POLLINATION AND REVEGETATION IN THE SOUTH WEST OF WESTERN AUSTRALIA

By V.M SAFFER, E.M. BROWN, S.D. HOPPER, J. DELL, R.T. WILLS, A.H. BURBIDGE and J.D. MAJER
C/- Western Australian Naturalists' Club, Perth, 6000

ABSTRACT

This report presents the results of a project undertaken by the Western Australian Naturalists' Club and funded by the Gordon Reid Foundation for Conservation. Aspects of pollination and revegetation in Western Australia were examined, the value of understorey to pollinators was tested and regeneration of planted stands of eucalypts following fire was monitored. The report is in six parts, namely Part 1, the floral component of survey sites and their flowering patterns, Part 2, bird presence and the foraging activities of honeyeaters, Part 3, fruit set, Part 4, the value of understorey, Part 5, regeneration following fire, and Part 6, general conclusions.

More flowering events were recorded in revegetated sites than in remnant sites used as controls. More species flowered during spring in revegetated sites than during the other seasons, whereas flowering in remnant sites was most prolific during winter. Fifty-six percent of all flowering species were myrtaceous and, of these, eucalypts accounted for 65%.

Honeyeaters accounted for 44% of all birds seen. Four generalist species, namely Brown, New Holland and Singing Honeyeaters and Red Wattlebirds made up a majority (78%) of honeyeaters seen. More honeyeaters were seen during spring. There was no significant difference in the numbers of honeyeaters seen per visit in revegetated and remnant sites.

Differences in fruit mass, seed mass and the number of seeds per fruit at different sites were not consistent within species and varied between species. Viability of seeds was generally high for all species tested and germinability ranged from 6% to 98%.

More birds and more honeyeaters were seen on the side of a road which included a dense, diverse understorey than on the other side of the road which consisted of a monoculture of *Acacia saligna* with no understorey. The number of birds did not change significantly before, during, or after the introduction of an artificial understorey to both sides of the road. However, honeyeaters foraged more frequently on the introduced understorey under the *Acacia saligna* than within the dense vegetation.

Of 11 nine and 13 year-old eucalypt species that were monitored 12 months after an intense wildfire, seven species reseeded, three resprouted and one did not regenerate (*Eucalyptus kondininensis*). Two

of the three species that resprouted are not native to Western Australia; the remaining species are endemic to the State. Repeat monitoring six months later, following summer, showed that most seedlings survived (between 35% and 100%) and, in some species, germination of additional seedlings occurred over summer.

As outlined above, there appeared to be greater floral productivity in areas of revegetation than in remnant patches. Concurrently, more birds and, in particular, generalist honeyeaters, were more abundant in revegetated areas and foraged from eucalypt species which were dominant. Honeyeaters were, apparently, effective pollen vectors; fruit set, viability and germinability was generally high. Revegetation with understorey appeared more attractive to honeyeaters than revegetation without understorey and revegetating with local, native resprouters is more likely to succeed in highly fire-prone environments than reseeders.

This study emphasises how much more there is to learn about restoration of the megadiverse communities of the south-west. It is clear that self-replacement as has occurred in post-glacial Europe and North America is most unlikely in the south-west. Therefore, the importance of protecting all that remains of native vegetation in the south-west is paramount. Such remnants will provide the vital sources of local seed and cuttings essential for restoring the incredibly complex and highly localised biodiversity for which the south-west has become world famous.

GENERAL INTRODUCTION

European settlement in Western Australia in 1827 marked the beginning of large tracts of land being cleared for an expanding human population. The extent and speed of this degradation of native biodiversity has slowed greatly and restorative processes are currently being implemented. Remaining fragments of remnant vegetation are being kept and expanses such as road verges, potential corridors and areas of non-arable land are being revegetated with native species. However, little attention has been paid to monitoring revegetation in order to assess the resumption of ecosystem function (Rathcke and Jules 1993, Whelan 1989). Indeed, the health of the remaining remnants also begs assessment.

The self-sustainability of all functional units within a landscape is dependent upon numerous, interrelated elements. For example, many floral components rely upon the effectiveness of pollinators for reproduction. The process of pollination involves the transfer of pollen from pollen-bearing surfaces of a flower to the receptive stigma, usually of a conspecific elsewhere for out-breeders. Of the common animal pollen vectors, namely birds, mammals and invertebrates, the potential pollination services of birds is most often noted due to their visibility, diurnal habits and relative ease of identification. Most mammalian pollinators are nocturnal and difficult to study (Carthew and Goldingay 1997, Saffer 1998), while the identification of invertebrate pollinators falls out of the scope of most observers.

Recently, Brown *et al.* (1997) compiled a database of specific observations of animals visiting flowers of native plants in Western Australia. This handbook was the result of a project funded by the Gordon Reid Foundation for Conservation and administered by the Western Australian Naturalists' Club. Within the text, the process of pollination was recognized as vital for plants to set seed for future generations. Brown *et al.* (1997) indicated that restoration generally concentrates on establishing plant communities and that it is assumed that the faunal community, including pollinators, will follow naturally. Following the publication of this handbook, members of the Western Australian Naturalists' Club considered it necessary to monitor more closely, and compare, pollinators in patches of remnant vegetation and compare them to pollinators in revegetated, regenerated and cleared areas. To gain information from diverse landscapes over vast areas, and to raise the awareness of the importance of pollination as a process needed for self-sustaining revegetation, funding was sought to conduct a community-based monitoring program. Once again the Gordon Reid Foundation of Conservation provided financial support.

Flowering patterns and the presence and foraging activities of birds in diverse landscapes in the south west of Western Australia were monitored from summer 1997 through to autumn 1999. Individuals in rural areas volunteered to conduct observations in remnant and revegetated sites both on and off their properties. Fruit was collected from selected plant species in these sites to assess the effectiveness of pollinators in terms of the viability and germinability of seed within the fruit. The results of this study are synthesized here and the results of two satellite studies, both of which relate to the selection of plant species in revegetation, are included. Of the satellite studies, the first examined differences in pollinator activity in revegetation with understorey versus revegetation without understorey, and the second assessed regeneration of revegetation following a major perturbation, namely fire. Common names are used for birds (see Appendix 1) and, because of regional differences in common names for plants, scientific names are used for plants (see Appendix 2).

SURVEY SITES

Seventy-six sites were monitored. These sites were selected by volunteers and many were part of a broader *Birds on Farms Project in Western Australia* 1996 - 1999 (Newbey 1999) conducted by Birds Australia. Sites included those with remnant vegetation, those that had been cleared and kept that way, sites that had been cleared and subsequently revegetated, and those which had been cleared and regenerated naturally without human intervention (Table 1, Photos 1, 2, 3 and 4). Within this latter category of regeneration, one had been burnt and two had been cleared and then flooded following heavy rains. The

Table 1. The number of sites in each category of vegetation.

Vegetation type		Number of sites
Remnant		29
Cleared:	no regeneration	2
Revegetation:		
	road verge	21
	on-farm	21
Regeneration:		
	following fire	1
	post clearing	2

Table 2. Latitude and longitude of sites surveyed and the numbers of sites and vegetation types at each location.

Location Number	Nearest town	Latitude	Longitude	Number of sites: at each location	in each category of vegetation: Remnant	Cleared	Regeneration	Revegetation
1	Kalbarri	27'54'	114'47'	1	1	0	0	0
2	Geraldton	28'33'	114'44'	2	0	0	0	2
3	Dongara	29'15'	114'57'	2	1	0	1	0
4	Mukinbudin	30'34'	118'29'	1	1	0	0	0
5	Bodalin	31'28'	118'24'	5	2	0	0	3
6	Merredin	31'31'	118'21'	4	4	0	0	0
7	Toodyay	31'40'	116'22'	3	0	0	1	2
8	Gidgegannup	31'43'	116'18'	3	2	0	0	1
9	Clackline	31'45'	116'34'	1	0	0	1	0
10	York	31'55'	116'38'	3	2	0	0	1
11	Nth Dandelup	32'30'	115'59'	3	0	0	0	3
12	Cuballing	32'49'	117'04'	4	1	0	0	3
13	Williams/Wagin	33'03'	116'53'	3	0	0	0	3
14	Burekup	33'19'	115'48'	4	2	0	0	2
15	Arthur River	33'28'	117'05'	4	3	0	0	1
16	Dardanup	33'29'	115'57'	4	4	0	0	0
17	Arthur River	33'35'	116'42'	1	0	0	0	1
18	Boyup Brook	33'47'	116'20'	8	0	0	0	8
19	Kojonup	33'56'	116'58'	3	1	1	0	1
20	Borden	34'00'	118'24'	1	0	0	0	1
21	Ongerup	34'02'	118'11'	1	0	0	0	1
22	Cranbrook	34'16'	117'36'	8	0	0	0	8
23	Northcliffe	34'40'	116'12'	2	1	0	0	1
24	Walpole	34'55'	116'52'	1	1	0	0	0
25	Torbay	35'05'	117'35'	4	3	1	0	0
				Subtotal	29	2	3	42
				Total				76

location of sites is shown in Table 2 and Figure 1.

PART I: FLORAL COMPONENT OF SURVEY SITES AND THEIR FLOWERING PATTERNS

INTRODUCTION

Pollen and nectar are, by far, the most widely used attractants offered by plants as rewards to potential pollinators (Simpson and Neff 1983). The patterns of food resource availability, therefore, influence pollinator visitation rates (Ford and Paton 1982, Paton 1988, Wills 1989, Pyke *et al.* 1989, Armstrong 1991, Saffer 1998). Indeed, close relationships have been shown between flower food resources and local and regional movements of Australian bird pollinators (Keast 1968, Paton 1982,

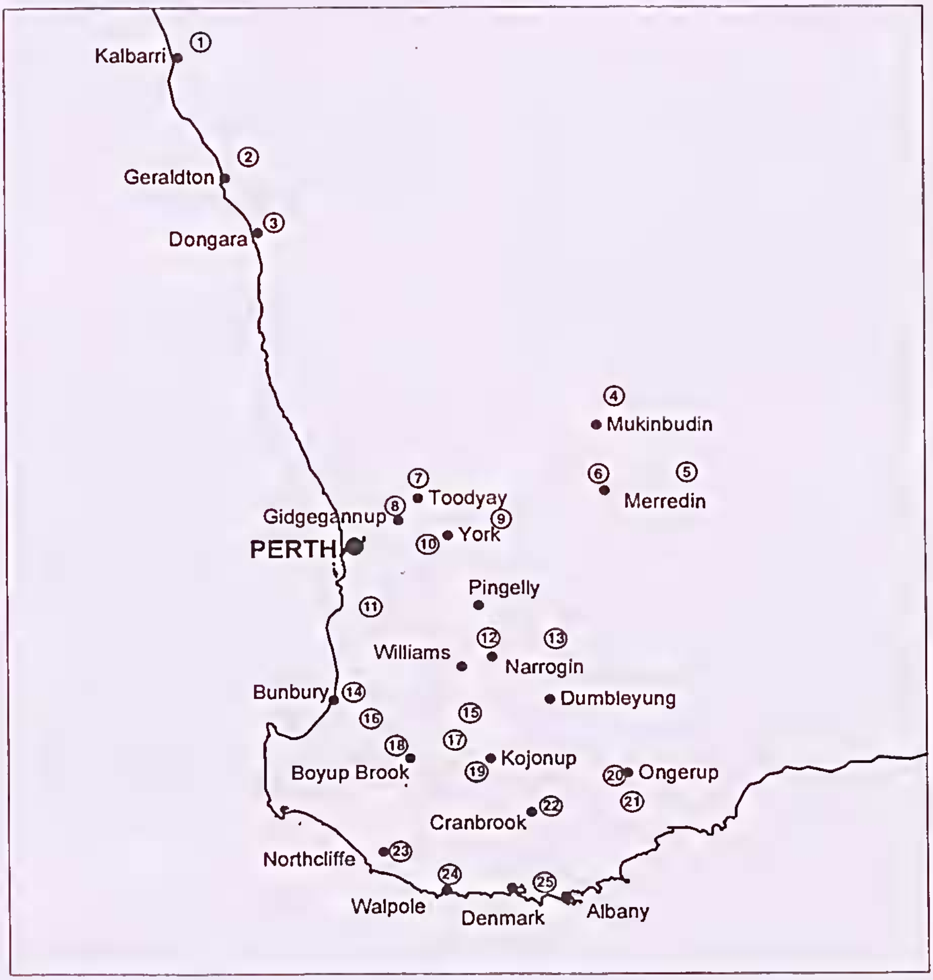


Figure 1. Map of south-western Australia. Circled numbers represent location of survey sites (see Table 2).

Paton 1985, Brown and Hopkins 1996). In this study, pollinator food resource availability was assessed during surveys by recording flowering patterns of major nectar-producing species.

METHODS

From summer 1997/98 to autumn 1999, once in each season, volunteers monitored 76 sites (Table 2, Figure 1). Initially, volunteers listed plant species present within each site; plants were then scored during seasonal surveys if they were flowering. Individual plants were scored as flowering if there was at least one flower open. The list of plant species on all sites is extensive. Therefore only those species that were recorded as flowering are included. Plants were identified using relevant keys (Grieve and Blackall 1975, Grieve 1980, Grieve 1981, Grieve 1988, Grieve 1998). Nomenclature followed Western Australian Herbarium (1999).

RESULTS

The number of flowering plants recorded during all surveys totaled 676 species (Table 3). Of these, a majority (446 = 66%) were flowering in revegetated sites (N = 42), followed by the number flowering in remnant sites (204 = 30%) (N = 29). Only 10 plants were recorded as flowering in regenerated sites and 15 in cleared sites.

The family Myrtaceae accounted for 56% of all flowering species, with 65% (N = 246) being eucalypts. Revegetated sites had more flowering events recorded (255) from more myrtaceous species (55) than in remnant sites (103 flowering events from 39 species). Proteaceous species numbered 119 (18%) and acacias (Mimosaceae) accounted for 11% (Table 3). A similar number of proteaceous species in revegetated sites (20 species) and in remnant sites (19 species) resulted in 71 and 48 flowering events respectively. More than ten species of acacias resulted in 58 flowering events in revegetated areas, whereas only 14 flowering events from five species were recorded in remnant sites. The remaining 107 flowering plants came from 21 families (see Table 3).

Within the revegetated sites, more species flowered during spring, followed by the number flowering during winter, whereas this pattern was reversed in the remnant sites (Table 3). The numbers of plants flowering in each season in the cleared and regenerated sites were so low as to be meaningless in terms of seasonal trends.

DISCUSSION

Habitat remnants and areas of revegetation exist as small ecological units, each the result of and subject to unique conditions (Ehrlich and Murphy 1987, Hobbs 1993). Patterns of flowering within these units are dependent on many factors which vary temporally and spatially (Wills 1989). Sites surveyed in this study spanned a vast area and were subject to a range of environmental conditions. There was also a large disparity in the number of sites monitored in each vegetation category. Therefore, caution must be exercised when making generalisations about the floral dynamics across different habitats (Ehrlich and Murphy 1987).

In this study, myrtaceous and proteaceous species together accounted for a majority (76%) of plants flowering in both remnant and revegetated sites. The dominance of these two families is not uncommon in Western Australian landscapes (Beard 1990, Wills *et al.* 1990). Overall, it appears that there was greater species diversity and productivity in revegetated sites than remnant sites. This difference may be an artefact of biased site-selection by the volunteers in terms of greater productivity, particularly with reference to revegetated sites. Nevertheless, the results indicate broadly that floral productivity in remnant areas may be in need of some restoration. Very little activity was recorded on regenerated and cleared sites and is not discussed further.

The seasonal patterns of flowering in this study may be related to the time observations were made and, therefore, may not accurately reflect patterns that occurred.

PART 2: BIRD PRESENCE AND THE FORAGING ACTIVITIES OF HONEYEATERS

Fragmentation and degradation of formerly continuous vegetation is likely to impact on plant-pollinator interactions and, consequently, on plant demography and recruitment (Rotenberry 1985, Aizen and Feinsinger 1994). The role of pollination is vital in the sustainability of remnant vegetation and in the process of restoration biology, yet has received little attention (Saunders and Ingram 1995, Neal 1998). In this study, the presence of avian pollinators was monitored in areas of varied vegetated status, and their activities recorded.

METHODS

From summer 1997/1998 to autumn 1999, once each season, volunteers monitored 76 sites (see Part 1 for methods and locality map). Areas ranging in size from 0.3ha to 0.5ha were surveyed by volunteers walking through each site for 20-30 minutes as early as possible each morning. Birds were scored if present at each site during each monitoring session, and the foraging activities of honeyeaters were noted where possible. Every attempt was made not to count the same bird twice.

RESULTS

Overall, 1004 sightings of 75 species of birds were recorded (Appendix 3). Of these, 44% (438 individuals of 16 species) were honeyeaters (Table 4), with Brown, New Holland and Singing Honeyeaters and Red Wattlebirds comprising 78% of all honeyeaters seen. Brown Honeyeaters were by far the most common species seen (Table 4).

More honeyeaters were recorded in revegetated areas (Table 4), followed by the numbers seen in remnant sites. However, the numbers of honeyeaters seen per visit in remnant, revegetated and regenerated sites were not significantly different ($F_{2,15}$= 1.827, P = 0.194). No honeyeaters were seen in cleared sites.

Combining the first and second seasons of summer (1997 and 1998) and autumn (1998 and 1999), more honeyeaters were seen, per visit, during the spring months in both remnant and revegetated sites than during autumn or winter, and the lowest numbers were seen per visit in summer for both vegetated states (Figure 2). More honeyeaters were sighted per visit in autumn in regenerated sites than during the other seasons (Figure 2).

Of the 438 honeyeaters seen during the surveys, 282 (64%) were observed foraging (Table 5). As more myrtaceous species were observed flowering overall,

Table 3. The number of plants flowering in survey sites from summer 1997 to autumn 1999.

Family Genus	species	Revegetated Sum 97	Revegetated Aut 98	Revegetated Win 98	Revegetated Spr 98	Revegetated Sum 98	Revegetated Aut 99	Remnant Sum 97	Remnant Aut 98	Remnant Win 98	Remnant Spr 98	Remnant Sum 98	Remnant Aut 99
Amaranthaceae													
Ptilotus	spp.				2	1							
Anacardiaceae													
Schinus	*terebinthifolia*			1									
Bignoniaceae													
Tecoma	*stans*			1									
Casuarinaceae													
Allocasuarina	*acutivalvis*									2			
Allocasuarina	*campestris*				1								
Allocasuarina	*huegeliana*				1								
Allocasuarina	sp.						1						
Casuarina	*obesa*		1		1		1						
Casuarina	spp.		1	5		4				3	2		
Cupressaceae													
Actinostrobus	*arenarius*										1		
Dilleniaceae													
Hibbertia	*acerosa*				1								
Hibbertia	*cuneiformis*								2	2		1	
Hibbertia	sp.							1	1		2	1	
Epacridaceae													
Astroloma	*serratifolium*							1	1				
Astroloma	spp.				1		2					1	
Leucopogon	spp.											2	
Goodeniaceae													
Dampiera	spp.				4								
Goodenia	sp.				1								
Scaevola	sp.				1								
Haemodoraceae													
Anigozanthos	*manglesii*				1								
Anigozanthos	sp.				1				1		1	1	
Iridaceae													
Patersonia	spp.			1	2								
Lamiaceae													
Westringia	spp.	2	1	1	1								
Lobeliaceae													
Isotoma	spp.				2								
Loranthaceae													
Nuytsia	*floribunda*					1			1			1	
Malvaceae													
Hibiscus	sp.						1						
Mimosaceae													
Acacia	*acuminata*									3	1		
Acacia	*celastrifolia*			2									
Acacia	*chrysella*										4		
Acacia	*decurrens*		1	1	1								

Cleared Sum 97	Cleared Aut 98	Cleared Win 98	Cleared Spr 98	Cleared Sum 98	Cleared Aut 99	Regenerated Sum 97	Regenerated Aut 98	Regenerated Win 98	Regenerated Spr 98	Regenerated Sum 98	Regenerated Aut 99	Total	Number in Family Total	Number in Family % of total
												3	3	0.4
												1	1	0.1
												1	1	0.1
												2	23	3.4
												1		
												1		
												1		
												3		
												15		
												1	1	0.1
												1	15	2.2
		1	1		1							8		
				1								6		
												2	8	1.2
												4		
												2		
												4	6	0.9
												1		
												1		
												1	5	0.7
												4		
												3	3	0.4
												5	5	0.7
												2	2	0.3
												3	3	0.4
												1	1	0.1
								1	1			6	74	10.9
												2		
												4		
												3		

Table 3. (continued).

Family Genus	species	Revegetated Sum 97	Aut 98	Win 98	Spr 98	Sum 98	Aut 99	Remnant Sum 97	Aut 98	Win 98	Spr 98	Sum 98	Aut 99
Mimosaceae (cont.)													
Acacia	*drummondii*			2									
Acacia	*lasiocarpa*									1			
Acacia	*pentadenia*										1		
Acacia	*prismifolia*		2										
Acacia	*pulchella*		2	6	1						3		
Acacia	*pycnantha*				1								
Acacia	*saligna*			2	1		7						
Acacia	*tetanophylla*			1									
Acacia	spp		3	12	6	2	1		1	2	1		1
Myrtaceae													
Agonis	*flexuosa*				2								
Agonis	*linearifolia*									1			
Agonis	*parviceps*									1			
Baeckea	*muricata*									1			
Beaufortia	*schaueri*											1	
Beaufortia	*squarrosa*				1						1	1	
Eucalyptus	*camaldulensis*	1		1	1	2	4		1		1	1	
Eucalyptus	*capillosa*									1		2	
Eucalyptus	*citriodora*		1							1			
Eucalyptus	*cladocalyx*	1	1										
Eucalyptus	*conferruminata*			1	1		1						
Eucalyptus	*diptera*		1										
Eucalyptus	*diversicolor*					1					1	2	2
Eucalyptus	*eremophila*			1	1								
Eucalyptus	*erythronema*											1	
Eucalyptus	*ficifolia*					2							
Eucalyptus	*gardneri*				3								
Eucalyptus	*globulus*			1						1			
Eucalyptus	*grandis*		1										
Eucalyptus	*kruseana*			1	1								
Eucalyptus	*lehmannii*					1				1	1	1	1
Eucalyptus	*leucoxylon*		3	2			2			1			
Eucalyptus	*longicornis*	1											
Eucalyptus	*loxophleba*			2	1			1		2			
Eucalyptus	*macrandra*		1	2		1	1						
Eucalyptus	*macrocarpa*			1									
Eucalyptus	*marginata*									1	4	1	1
Eucalyptus	*megacarpa*					1							
Eucalyptus	*mellidora*			1									
Eucalyptus	*micranthera*						1						
Eucalyptus	*microcorys*					1							
Eucalyptus	*occidentalis*	1	6	5		1	6			1			
Eucalyptus	*patens*					1						3	1
Eucalyptus	*platycorys*									1			

Cleared						Regenerated						Total	Number in Family	
Sum 97	Aut 98	Win 98	Spr 98	Sum 98	Aut 99	Sum 97	Aut 98	Win 98	Spr 98	Sum 98	Aut 99		Total	% of total
												2		
												1		
												1		
												2		
												12		
												1		
												10		
												1		
												29		
			1	1	1							5	253	37.4
												1		
												1		
												1		
												1		
												3		
												12		
												3		
												2		
												2		
												3		
												1		
												6		
												2		
												1		
												2		
												3		
												2		
												1		
												2		
												5		
												8		
												1		
												6		
												5		
												1		
												7		
												1		
												1		
												1		
												1		
												20		
												5		
												1		

Table 3. (continued).

Family Genus	species	Revegetated Sum 97	Aut 98	Win 98	Spr 98	Sum 98	Aut 99	Remnant Sum 97	Aut 98	Win 98	Spr 98	Sum 98	Aut 99
Myrtaceae (cont.)													
Eucalyptus	*platypus*	1	3	1	2	4							
Eucalyptus	*robusta*		1		1								
Eucalyptus	*rudis*				3		3						
Eucalyptus	*salubris*							1					
Eucalyptus	*sargentii*			1	2	1							
Eucalyptus	*sideroxylon*		1	1									
Eucalyptus	*spathulata*	1	2	5	4	2	1						
Eucalyptus	*tetraptera*			2									
Eucalyptus	*torquata*	1	1	1									
Eucalyptus	*wandoo*	1			2	2	1	1	1	3	3	2	2
Eucalyptus	spp.			3	2	2	2			1			1
Hypocalymma	*angustifolium*				1								
Kunzea	*affinis*				1								
Kunzea	*baxteri*			2									
Kunzea	*pulchella*							1		1			
Leptospermum	*fastigiatum*												1
Leptospermum	spp.			1	1				1	1	1	1	
Melaleuca	*acuminata*				1								
Melaleuca	*corrugata*							1					
Melaleuca	*cuticularis*				1								
Melaleuca	*lateritia*				1								
Melaleuca	*nesophila*	1				6							
Melaleuca	*pungens*				2								
Melaleuca	*uncinata*								1	1			
Melaleuca	spp.	2	2	3	7	2	1			1	3		
Prunis	*cerasifera*									1			
Thryptomene	*kochii*									2			
Verticordia	spp.				3								
Myrtaceae	sp.							1	1				
Papilionaceae													
Cytisus	*proliferus*			3	2								
Gastrolobium	*parvifolium*										1		
Gastrolobium	*trilobum*										1		
Gastrolobium	sp.				1								
Jacksonia	spp.			1	1								
Kennedia	*prostrata*				1								
Pittosporaceae													
Billardiera	*bicolor*											1	
Billardiera	sp.				1								
Sollya	*heterophylla*				2								
Sollya	sp.				1								
Proteaceae													
Adenanthos	sp.										1		
Banksia	*ashbyi*						1						
Banksia	*attenuata*								1	1	2	1	1
Banksia	*burdettii*						1						

Cleared						Regenerated						Total	Number in Family	
Sum 97	Aut 98	Win 98	Spr 98	Sum 98	Aut 99	Sum 97	Aut 98	Win 98	Spr 98	Sum 98	Aut 99		Total	% of total
												11		
												2		
												6		
												1		
												4		
												2		
												15		
												2		
												3		
							1		1	1	1	22		
												11		
												1		
												1		
												2		
												2		
												1		
												6		
												1		
												1		
												1		
												1		
												7		
												2		
												2		
												21		
												1		
												2		
												3		
												2		
								1				6	12	1.8
												1		
												1		
												1		
												2		
												1		
												1	5	0.7
												1		
												2		
												1		
												1	119	17.6
												1		
												6		
												1		

Table 3. (continued).

Family Genus	species	Revegetated Sum 97	 Aut 98	 Win 98	 Spr 98	 Sum 98	 Aut 99	Remnant Sum 97	 Aut 98	 Win 98	 Spr 98	 Sum 98	 Aut 99
Proteaceae (cont.)													
Banksia	*grandis*										1		
Banksia	*ilicifolia*								1	1	1	1	1
Banksia	*littoralis*		1										
Banksia	*menziesii*								1			1	1
Banksia	*prionotes*		1	1			1		1			1	1
Banksia	*sceptrum*							1				1	
Banksia	*sphaerocarpa*		1	1			1		1	1			1
Banksia	spp.		1	1	1					1		1	1
Dryandra	*carduacea*										2		
Dryandra	*nobilis*									1			
Dryandra	*sessilis*		1	3			1		2	1	1		
Dryandra	spp.										3		
Grevillea	*acacioides*				1	1							
Grevillea	*curviloba*				1								
Grevillea	*drummondii*			1									
Grevillea	*hookeriana*			1									
Grevillea	*paradoxa*								1	1			
Grevillea	*thelemanniana*			1									
Grevillea	*wilsonii*		1										
Grevillea	spp.	1	4	7	7	3	3			1	1		
Hakea	*laurina*		1	7			3						
Hakea	*lissocarpha*									1			
Hakea	*multilineata*			1									
Hakea	*petiolaris*						1						
Hakea	*preissii*			1									
Hakea	*trifurcata*			1	1	1				1		1	
Hakea	sp.		1	2	1		1	1		1			
Xylomelum	*angustifolium*							1				1	
Rutaceae													
Chorilaena	*quercifolia*			2									
Diplolaena	*dampieri*										1		
Diplolaena	sp.									1	1		
Philotheca	*hassellii*									1		1	
Stylidiaceae													
Stylidium	sp.				1								
Thymelaeaceae													
Pimelea	sp.				1								
Violaceae													
Hybanthus	*floribundus*								1	1			
Xanthorrhoeaceae													
Xanthorrhoea	*preissii*									1	1		
Total flowering events				446						205			
Seasonal totals		305	342	400	391	338	350	300	312	349	337	324	319

Cleared Sum 97	Aut 98	Win 98	Spr 98	Sum 98	Aut 99	Regenerated Sum 97	Aut 98	Win 98	Spr 98	Sum 98	Aut 99	Total	Number in Family Total	% of total
												1		
												5		
												1		
												3		
												6		
												2		
												6		
												6		
												2		
												1		
												9		
												3		
												2		
												1		
												1		
												1		
												2		
												1		
												1		
												27		
												11		
												1		
												1		
												1		
												1		
												5		
												7		
												2		
												2	7	1.0
												1		
												2		
												2		
												1	1	0.1
												1	1	0.1
												2	2	0.3
												2	2	0.3
		15						10				553		
291	294	295	296	296	299	291	295	296	296	295	298			

Table 4. The number of honeyeaters present, seasonally, during surveys at remnant, revegetated and regenerated sites from summer 1997 to autumn 1999 and the number of honeyeaters recorded per visit per site. Sum = summer, Aut = autumn, Win = winter, Spr = spring.

	Remnant						Revegetated						Regenerated						Total	Cumulative total %
	Sum 97	Aut 98	Win 98	Spr 98	Sum 98	Aut 99	Sum 97	Aut 98	Win 98	Spr 98	Sum 98	Aut 99	Sum 97	Aut 98	Win 98	Spr 98	Sum 98	Aut 99		
Brown Honeyeater	1	5	5	13	4	7	4	19	17	25	6	7	1	0	2	1	0	2	119	27.2%
New Holland Honeyeater	0	4	5	5	6	5	2	13	13	12	7	6	0	0	0	0	0	0	78	17.8%
Singing Honeyeater	1	3	5	7	3	3	5	8	9	8	11	7	0	0	1	0	2	1	74	16.9%
Red Wattlebird	0	4	7	9	3	3	1	8	9	13	6	8	0	1	0	0	0	0	72	16.4%
Yellow-throated Miner	1	1	2	0	0	4	1	4	1	5	2	2	0	1	0	0	0	0	24	5.5%
Western Spinebill	0	0	1	3	2	2	0	2	1	1	1	3	0	0	0	0	0	0	16	3.7%
Little Wattlebird	0	0	0	1	0	0	0	1	1	8	1	1	0	0	0	0	0	0	13	3.0%
White-naped Honeyeater	0	0	2	1	0	1	0	3	2	1	1	0	0	0	0	0	0	0	11	2.5%
White-cheeked Honeyeater	0	1	1	2	0	1	1	0	1	0	1	0	0	1	1	0	0	1	11	2.5%
Brown-headed Honeyeater	0	0	2	1	0	0	1	0	2	0	0	0	0	0	0	1	0	0	7	1.6%
Spiny-cheeked Honeyeater	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0.7%
White-plumed Honeyeater	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2	0.5%
Yellow-plumed Honeyeater	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0.5%
Purple-gaped Honeyeater	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0.2%
White-eared honeyeater	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0.2%
White-fronted Honeyater	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.2%
Wattlebird (Species unknown)	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	3	0.7%
Total	5	19	31	43	18	26	16	59	60	75	36	34	1	3	4	2	2	4	438	
Number of sites	29	29	29	29	29	29	42	42	42	42	42	42	3	3	3	3	3	3	76	
Number of times each vegetation type was visited	8	21	25	23	24	25	7	34	40	38	39	35	1	3	3	3	3	2		
No. honeyeaters/visit/site	0.6	0.9	1.2	1.9	0.8	1.0	2.3	1.7	1.5	2.0	0.9	1.0	1.0	1.0	1.3	0.7	0.7	2.0		

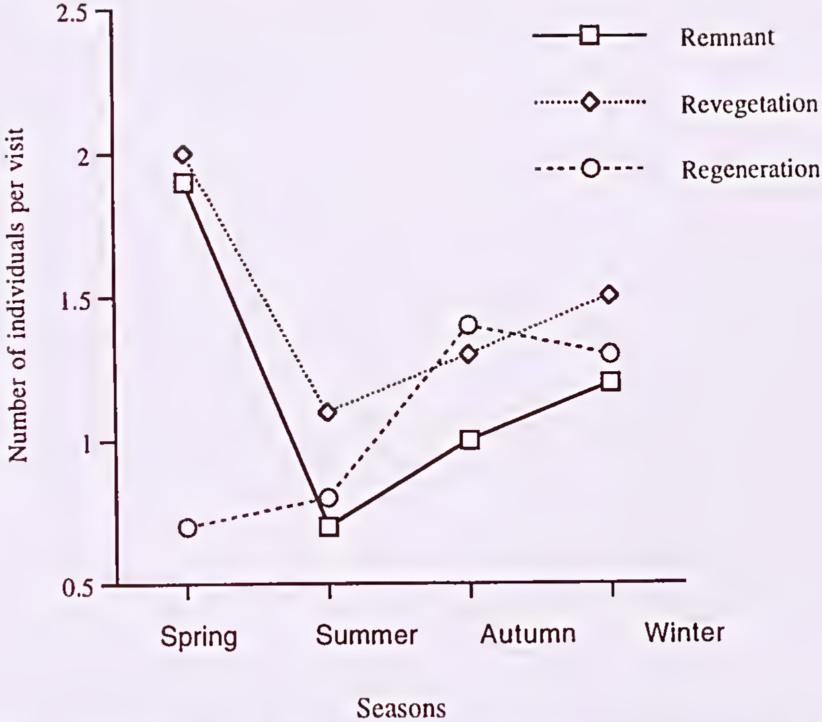


Figure 2. Seasonal variation in the number of honeyeaters seen per visit in remnant, revegetated and regenerated sites

it was not surprising that honeyeaters were seen foraging at myrtaceous species (66% of observations) more than at other species. Similarly, more honeyeaters were seen foraging at eucalypts (73%) than at other species within Myrtaceae. Foraging at proteaceous species accounted for 24% of foraging observations, 5% of honeyeaters foraged at acacias within the Mimosaceae and the remaining 5% of honeyeaters foraged at species from seven other families (Table 5).

DISCUSSION

Studies of changes in the distribution and abundance of birds have been conducted in the wheatbelt (Saunders and Ingram 1995, Arnold and Weeldenburg 1998) and in other areas of remnant vegetation in Western Australia (Keast *et al.* 1985). Saunders and Ingram (1995) demonstrated a decline in passerine species in fragmented patches of remnant vegetation, and suggested that many populations may be too small to be viable and too isolated to allow the remnant to be recolonized if the population is lost (see also Arnold and Weeldenburg 1998). Other studies found increases in some species such as the Galah, Little Corella, Long-billed Corella and Red-tailed Black Cockatoo which all feed on the cereal crops and

Table 5. The number of honeyeaters seen foraging and the plant families upon which honeyeaters foraged.

	Number of birds foraging	Plant families			
		Myrtaceae	Proteaceae	Mimosaceae	Others*
Brown Honeyeater	80	57	17	2	4
New Holland Honeyeater	59	38	17		4
Red Wattlebird	44	29	8	3	4
Singing Honeyeater	38	31	4	2	1
Yellow-throated Miner	15	11	1	3	
Western Spinebill	12	3	9		
Little Wattlebird	11	2	5	3	1
White-naped Honeyeater	6	5	1		
White-cheeked Honeyeater	5	3	2		
Brown-headed Honeyeater	4	3	1		
White-plumed Honeyeater	2	1	1		
Yellow-plumed Honeyeater	2	2			
Spiny-cheeked Honeyeater	1		1		
Purple-gaped Honeyeater	1	1			
White-eared honeyeater	1	1			
White-fronted Honeyater	1		1		
Total	282	187	68	13	14
%	100	66.3	24.1	4.6	5.0

*Anacardiaceae, Bignoniaceae, Dilleniaceae, Haemodoraceae, Papillionaceae, Rutaceae, Xanthorrhoeaceae

agricultural weeds available in the surrounding farmlands (Saunders *et al.* 1985).

This study aimed to determine if birds, with particular emphasis on honeyeaters, remained in patches of remnant vegetation, and to compare these findings to the diversity and abundance of birds in areas of revegetation. Birds appeared in all vegetation types, except cleared areas, with no significant difference between species in the different vegetated states. Honeyeaters constituted a sizeable percentage of birds present. Four generalist species, namely Brown, New Holland and Singing Honeyeaters and Red Wattlebirds made up a majority of honeyeaters seen, and these species were present in remnant, revegetated and regenerated survey sites. It was not surprising that honeyeaters were not seen in cleared areas, where neither floral rewards nor potential nest sites were available.

Generally, more honeyeaters were seen during the spring. This may be a time of maximum breeding, seasonal visitation by nomadic or migratory species, or a time of dispersal of fledglings (Keast 1968, Recher and Holmes 1985). This time of maximum bird numbers coincides with spring flowering of many plant species. Invertebrates form part of the diet of all honeyeaters, albeit to varying degrees (Pyke 1983, Collins *et al.* 1990). It seems reasonable to assume that honeyeaters foraging on plant species which do not produce nectar in quantities sufficient to attract honeyeaters, such as acacias and others (see Table 5), were foraging for insects which were visiting flowers of these species.

The results indicate that generalist honeyeaters foraged on generalist plant species, particularly in revegetated stands. Although honeyeaters were observed foraging from species within numerous families, eucalypt species were the most frequented. In spite of these observations, the effectiveness of honeyeaters as pollinators may not be as anticipated. The efficiency of pollinator activity is discussed in the next section.

PART 3: FRUIT SET

INTRODUCTION

The reproductive success of a flowering plant may be measured by the number of its offspring present or by the determination of fertile seed in fruit on, or shed by, the mature plant (Ladd and Connell 1994, van Leewen and Lamont 1996). Once viable seeds are set, factors that affect the ability of the seed to produce a seedling include loss of viability, dormancy and other factors affecting germination (Schatral and Osborne 1994, Adkins and Bellairs 1997, Bell 1999).

Normally, the efficiency of pollinators is documented by counting numbers of pollen grains on stigmas before and after floral visitation. However, this was not possible in the present study due to cost and time constraints. Consequently, we determined, indirectly, the efficiency of avian pollinators by assessing fruit set, using viability and germinability of seed as indicators of successful pollination. In this study, fruit from sites of varied vegetation was collected so that reproductive fecundity could be compared.

METHODS

Fruit was collected by volunteers (Photos 5 and 6) from species known to be used by honeyeaters in their survey sites and from species present at more than one site. Fruit was harvested from nine plant species: seven myrtaceous species (five species of eucalypt and two *Calothamnus* species), and two proteaceous species (both hakeas) (Table 6). Overstorey species, such as *Eucalyptus burracoppinensis*, *E. calophylla*, *E. marginata* and *E. wandoo*, originated from remnant sites and the mid-storey species such as *E. platypus*, and *Hakea laurina* originated from revegetated sites. *Hakea trifurcata*, another mid-storey species, was harvested from a remnant site and from an adjacent site that was regenerating following fire. The two understorey species (*Calothamnus* spp.) were collected from revegetated sites.

FRUIT AND SEED CHARACTERISTICS

Within each survey site, ten plants of a species were selected and ten fruit were harvested from each of the ten individuals of that species (100 fruit in total). Each fruit was placed in an individually-labelled envelope and stored at room temperature until assessed. In the laboratory, each fruit was weighed in grams to three decimal points. Seed was then extracted from the fruit and separated from extraneous material. The number of seeds per fruit was counted and weighed. The cleaned seed from the ten fruit of each plant was bulk stored in individually labelled polycarbonate tubes.

Table 6. Mean (± s.e.) fruit mass (g) per plant and mean (± s.e.) seed mass (g) per fruit. Location and vegetation status are included. Significant differences are in bold. Superscripts refer to different sites at one location.

	Location	Vegetation status	Fruit mass: Mean ± s.e. (g)	Fruit mass: Number of fruit	Fruit mass: Differences between samples	Seed mass: Mean ± s.e. (g)	Seed mass: Number of fruit	Seed mass: Differences between samples
Eucalyptus burracoppenensis								
6	Merredin	remnant	3.4 ± 0.186	10	$F_{2,207}$ = 18.08, **P <0.001**	0.036 ± 0.005	10	$F_{2,203}$ = 1.57, P = 0.210
6	Merredin	remnant	3.0 ± 0.081	100		0.021 ± 0.004	96	
5	Bodallin	remnant	2.3 ± 0.106	100		0.016 ± 0.004	100	
Eucalyptus calophylla								
16	Dardanup	remnant	6.3 ± 0.240	100	$F_{5,482}$ = 36.10, **P <0.001**	0.026 ± 0.010	98	$F_{5,480}$ = 73.13, **P <0.001**
14	Burekup	remnant	5.7 ± 0.220	100		0.157 ± 0.015	100	
24	Walpole	remnant	2.6 ± 0.600	20		0.000 ± 0.000	20	
8	Gidgegannup	remnant	13.9 ± 0.280	100		0.410 ± 0.020	100	
25	Torbay	remnant	8.4 ± 1.000	99		0.139 ± 0.014	99	
10	York	remnant	7.7 ± 0.510	69		0.200 ± 0.022	69	
Eucalyptus marginata								
24	Walpole	remnant	1.16 ± 0.060	10	$F_{2,206}$ = 3.98, **P = 0.0201**	0.000 ± 0.000	10	$F_{2,206}$ = 1.002, P = 0.369
23	Nothcliffe	remnant	0.83 ± 0.040	99		0.013 ± 0.003	99	
25	Torbay	remnant	0.85 ± 0.030	100		0.014 ± 0.003	100	
Eucalyptus platypus								
11	Nth Dandelup	revegetation	0.25 ± 0.007	100	$F_{2,297}$ = 124.35, **P <0.001**	0.002 ± 0.000	85	$F_{2,241}$ = 36.87, **P <0.001**
21	Ongerup	revegetation	0.13 ± 0.006	100		0.001 ± 0.000	99	
20	Borden	revegetation	0.33 ± 0.013	100		0.004 ± 0.000	62	
Eucalyptus wandoo								
14	Burekup	remnant	0.09 ± 0.010	100	$t_{1,137}$ = 4.976, **P <0.001**	0.002 ± 0.000	96	$t_{1,124}$ = 3.799, **P <0.001**
10	York	remnant	0.07 ± 0.006	39		0.001 ± 0.000	30	

Calothamnus quadrifidus											
8	Gidgegannup	revegetation	0.21	± 0.005	100	$F_{2,296} = 111.51$, $P < 0.001$	0.003	± 0.000	83	$F_{2,272} = 7.877$, $P < 0.001$
13	Williams/Wagin	revegetation	0.19	± 0.004	100		0.004	± 0.000	94	
22	Cranbrook	revegetation	0.12	± 0.004	99		0.002	± 0.000	98	
Calothamnus rupestris											
18	Boyup Brook[1]	revegetation	0.91	± 0.023	100	$t_{1,198} = 2.058$, $P = 0.040$	0.280	± 0.002	100	$t_{1,198} = 0.483$, $P = 0.630$
18	Boyup Brook[2]	revegetation	0.85	± 0.022	100		0.031	± 0.005	100	
Hakea laurina											
22	Cranbrook[1]	revegetation	4.13	± 0.116	100	$t_{1,198} = 1.839$, $P = 0.067$	0.041	± 0.002	100	$t_{1,198} = 2.193$, $P = 0.030$
22	Cranbrook[2]	revegetation	3.85	± 0.099	100		0.063	± 0.010	100	
Hakea trifurcata											
3	Dongara[1]	regeneration	0.19	± 0.004	100	$t_{1,188} = 0.273$, $P = 0.784$	0.028	± 0.002	99	$t_{1,187} = 1.493$, $P = 0.137$
3	Dongara[2]	remnant	0.19	± 0.012	90		0.033	± 0.003	90	

The data recorded were used to derive mean values for:

- mass of fruit for each plant;
- mass of seed per fruit;
- number of seed per fruit;
- mass of an individual seed from each plant and the number of seeds in 1 gm.

VIABILITY

Viability was estimated by a simple 'cut test' to determine if healthy endosperm was present. Up to 50 seeds per species were tested, or less where under 50 seeds were available.

GERMINABILITY

Seeds were sown in standard nursery seedling punnets containing a pasteurised 1:1:1 coarse sand : composted sawdust : peat soil mix. The soil mix was moistened to field capacity with a Previcure® fungicide solution (7.5 mL per L) to reduce the risk of fungal attack prior to sowing the seed. Seed was randomly selected from the bulked samples for each plant, and sown on the surface of the soil mix. The number of seeds sown in each punnet differed between species and varied according to the number of seeds available (Table 7).

The seed was buried beneath a layer of pasteurised white sand (passed through a 0.5 mm mesh) to a depth not exceeding the diameter of the seed. Punnets were then sprayed with Previcure® fungicide solution to moisten the white sand layer.

The punnets were placed in either a refrigerated incubator at a constant temperature of 18°C or, depending on space availability at the time, in a tunnel house with fluctuating ambient temperature. The punnets were subsequently hand watered with

Table 7. Mean (± s.e.) number of seeds per fruit. Location, vegetation status, weight per seed and the number of seed per gram are included. Significant differences are in bold. Superscripts refer to different sites at one location.

	Location	Vegetation status	Number of fruit	Number of seed per fruit		Weight of one seed		Number of seed in 1 g
				Mean ± s.e.	Differences between samples	Number of fruit	Mean ± s.e. (g)	Mean ± s.e.
Eucalyptus burracoppenensis								
6	Merredin	remnant	10	35.5 ± 4.94	$F_{2,207} = 23.38, P < 0.001$	10	0.001 ± 0.000	977.3 ± 71.6
6	Merredin	remnant	100	16.6 ± 1.85		84	0.001 ± 0.000	1419.0 ± 105.0
5	Bodallin	remnant	100	7.8 ± 0.64		90	0.001 ± 0.000	835.8 ± 58.8
Eucalyptus calophylla								
16	Dardanup	remnant	98	0.35 ± 0.09	$F_{5,479} = 45.89, P < 0.001$	18	0.040 ± 0.006	38.4 ± 6.9
14	Burekup	remnant	100	3.48 ± 0.22		91	0.045 ± 0.003	30.8 ± 1.9
24	Walpole	remnant	20	0.05 ± 0.05		1	0.003	
8	Gidgegannup	remnant	100	2.74 ± 0.15		92	0.156 ± 0.004	6.9 ± 0.2
25	Torbay	remnant	99	2.07 ± 0.20		58	0.680 ± 0.002	13.5 ± 1.2
10	York	remnant	69	1.70 ± 0.18		47	0.119 ± 0.004	9.5 ± 0.7
Eucalyptus marginata								
24	Walpole	remnant	10	0.00 ± 0.00	$F_{2,206} = 5.42, P = 0.005$	0		
23	Nothcliffe	remnant	99	4.61 ± 1.07		24	0.002 ± 0.000	407.1 ± 25.3
25	Torbay	remnant	100	1.40 ± 0.14		65	0.010 ± 0.001	157.7 ± 12.5
Eucalyptus platypus								
11	Nth Dandelup	revegetation	100	2.36 ± 0.22	$F_{2,296} = 20.11, P < 0.001$	59	0.001 ± 0.000	1826.1 ± 139.1
21	Ongerup	revegetation	99	0.90 ± 0.25		22	0.047 ± 0.045	1087.2 ± 127.6
20	Borden	revegetation	100	5.11 ± 0.75		59	0.001 ± 0.000	2188.3 ± 184.6
Eucalyptus wandoo								
14	Burekup	remnant	100	2.87 ± 0.26	$t_{1,135} = 1.56, P = 0.121$	81	0.001 ± 0.000	2001.0 ± 148.2
10	York	remnant	37	2.14 ± 0.30		22	0.001 ± 0.000	2121.2 ± 67.8

Calothamnus quadrifidus							
8	Gidgegannup revegetation	98	22.71 ± 1.22	$F_{2,293}$ = 3.848, P = 0.022	73	<0.000	10382.8 ± 512.7
13	Williams/Wagin revegetation	100	23.42 ± 1.82		84	<0.000	7523.0 ± 338.5
22	Cranbrook revegetation	98	17.90 ± 1.47		77	<0.000	8511.7 ± 496.3
Calothamnus rupestris							
18	Boyup Brook[1] revegetation	100	101.60 ± 5.82	$t_{1,198}$ = 1.272, P = 0.205	99	<0.000	3955.3 ± 140.0
18	Boyup Brook[2] revegetation	100	91.52 ± 5.37		99	<0.000	4279.1 ± 218.5
Hakea laurina							
22	Cranbrook[1] revegetation	100	1.78 ± 0.06	$t_{1,198}$ = 0.639, P = 0.524	89	0.023 ± 0.001	49.2 ± 3.7
22	Cranbrook[2] revegetation	100	1.72 ± 0.07		86	0.036 ± 0.005	40.9 ± 1.9
Hakea trifurcata							
3	Dongara[1] regeneration	100	2.00 ± 0.00	$t_{1,188}$ = 1.847, P = 0.066	98	0.014 ± 0.001	106.7 ± 10.9
3	Dongara[2] remnant	90	1.93 ± 0.04		87	0.017 ± 0.001	88.6 ± 7.1

scheme water as required, in order to maintain a damp but not wet soil mix.

The punnets were checked daily for germinants with germination recorded upon the appearance of the coleoptile above the soil surface. Seedlings were pricked out following emergence to facilitate progressive counts and reduce the risk of fungal infection of the punnet. Germination was scored for a period of forty days.

RESULTS

FRUIT AND SEED CHARACTERISTICS

Fruit mass from different sites within species was significantly different for all species, save the hakeas (Table 6). Differences in seed mass within species was not as consistent, with three eucalypt species significantly different (*E. calophylla*, *E. platypus* and *E. wandoo*), and *C. quadrifidus* and *H. laurina* significantly different (Table 6). The number of seeds in *C. quadrifidus* fruit was also significantly different between sites but not so for *C. rupestris*, the two hakeas or *E. wandoo* (Table 7). Differences between seed numbers in the remaining eucalypt species were significant.

ESTIMATED VIABILITY

Overall, estimated viability was greater than 50% for 19 out of the 23 species tested (Table 8). Indeed, for each species tested, estimated viability of seeds from at least one site was greater than 50%, and for up to 44% of all species tested, estimated viability was greater than 75%.

GERMINABILITY

Dormancy was not marked in any of

Table 8. Viability of seed and the number of seed tested. Location and vegetation status are included. Superscripts refer to different sites at one location.

Location		Vegetation status	% viability Mean	±	s.e.	Number of seeds
Eucalyptus burracoppenensis						
6	Merredin	remnant	54.6	±	11.3	466
5	Bodallin	remnant	79.5	±	6.7	267
Eucalyptus calophylla						
16	Dardanup	remnant	25.0	±	17.1	15
14	Burekup	remnant	24.4	±	9.4	129
8	Gidgegannup	remnant	84.1	±	10.8	86
25	Torbay	remnant	80.0	±	5.8	82
10	York	remnant	62.1	±	17.8	48
Eucalyptus marginata						
24	Walpole	remnant	13.0	±	13.0	49
25	Torbay	remnant	54.7	±	13.4	27
Eucalyptus platypus						
11	Nth Dandelup	revegetation	24.8	±	10.4	84
21	Ongerup	revegetation	58.2	±	23.8	44
20	Borden	revegetation	74.4	±	14.2	323
Eucalyptus wandoo						
14	Burekup	remnant	66.8	±	10.6	126
10	York	remnant	83.3	±	11.8	19
Calothamnus quadrifidus						
8	Gidgegannup	revegetation	80.4	±	6.8	450
13	Williams/Wagin	revegetation	83.5	±	9.7	489
22	Cranbrook	revegetation	95.9	±	1.8	691
Calothamnus rupestris						
18	Boyup Brook[1]	revegetation	97.1	±	1.8	500
18	Boyup Brook[2]	revegetation	96.1	±	2.1	500
Hakea laurina						
22	Cranbrook[1]	revegetation	70.0	±	10.2	46
22	Cranbrook[2]	revegetation	60.0	±	13.3	43
Hakea trifurcata						
3	Dongara[1]	regeneration	69.6			30
3	Dongara[2]	remnant	87.9			65

the species tested, with the first germinant appearing before day 10 for most species (Table 9). First germinants in the two species of hakeas appeared latest, but no later than day 15 for *H. laurina*. The day of the last germinant was as early as day 16 for *E. wandoo*, and as late as day 37 for *E. burracoppinensis*. With few exceptions, both first and last germinants appeared

Table 9. Day of the appearance of first germinant, last germinant and maximum germination, followed by sample sizes. Location and vegetation status are included. Superscripts refer to different sites at one location.

Location	Vegetation status	Day of first germinant	Day of last germinant	Maximum germination % Mean ± s.e	Sample size Number of punnets (No. seeds per punnet)
Eucalyptus burracoppenensis					
6 Merredin	remnant	8	37	66.4 ± 5.2	9 (20)
5 Bodallin	remnant	6	37	72.2 ± 5.4	11 (20)
Eucalyptus calophylla					
16 Dardanup	remnant	6	17	20.0 ± 0.0	1 (10)
14 Burekup	remnant	8	29	33.0 ± 11.5	10 (10)
8 Gidgegannup	remnant	6	23	81.0 ± 4.8	10 (10)
25 Torbay	remnant	8	18	51.4 ± 13.9	7 (6-10)
10 York	remnant	8	17	72.0 ± 8.0	5 (10)
Eucalyptus marginata					
23 Northcliffe	remnant	11	17	5.8 ± 5.8	6 (10-20)
25 Torbay	remnant	8	25	27.5 ± 5.3	8 (10)
Eucalyptus platypus					
11 Nth Dandelup	revegetation	8	34	47.9 ± 11.8	9 (9-10)
21 Ongerup	revegetation	10	33	67.1 ± 10.6	7 (9-10)
20 Borden	revegetation	9	33	59.7 ± 6.4	10 (6-10)
Eucalyptus wandoo					
14 Burekup	remnant	8	16	60.9 ± 8.1	11 (10)
10 York	remnant	8	16	97.5 ± 2.5	6 (10)
Calothamnus quadrifidus					
8 Gidgegannup	revegetation	6	32	74.5 ± 9.3	10 (20)
13 Williams/Wagin	revegetation	6	28	87.5 ± 3.1	10 (20)
22 Cranbrook	revegetation	6	24	69.0 ± 10.0	10 (20)
Calothamnus rupestris					
18 Boyup Brook[1]	revegetation	10	33	84.5 ± 8.1	10 (20)
18 Boyup Brook[2]	revegetation	13	34	68.5 ± 11.0	10 (20)
Hakea laurina					
22 Cranbrook[1]	revegetation	15	37	91.0 ± 4.8	10 (10)
22 Cranbrook[2]	revegetation	15	34	85.0 ± 3.7	10 (10)
Hakea trifurcata					
3 Dongara[1]	regeneration	11	19	41.0 ± 7.2	10 (10)
3 Dongara[2]	remnant	12	21	34.0 ± 11.0	10 (10)

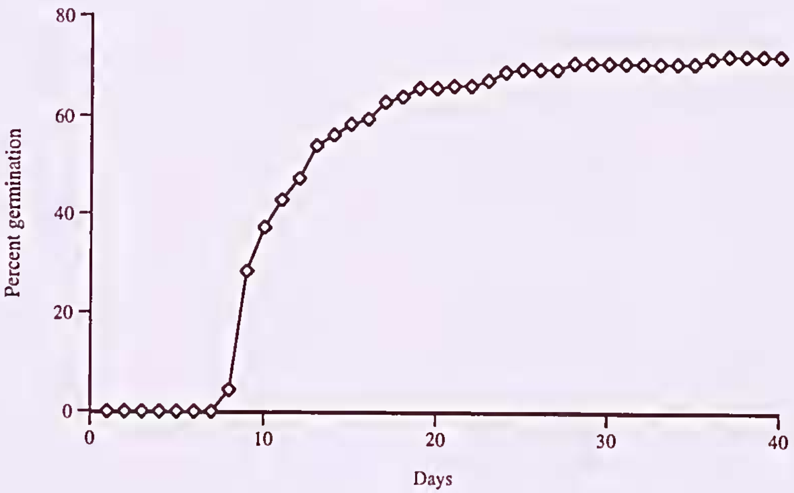
relatively consistently within species from different sites. For example, last germinants appeared 8 days apart between days 24 to 32 for *C. quadrifidus*.

Germination was greater than 50% for

16 out of the 23 species tested (70%) and less than 50% for the remaining 7 species tested (30%). Percentage germination was consistent within most species: greater sample sizes may reveal greater differences such as the differences evident in *E. calophylla* with a sample size of 5 and the greatest differences in percent germination (from 20% to 81%).

Two patterns of germination were evident between the species (Figure 3).

Pattern 1.



Pattern 2.

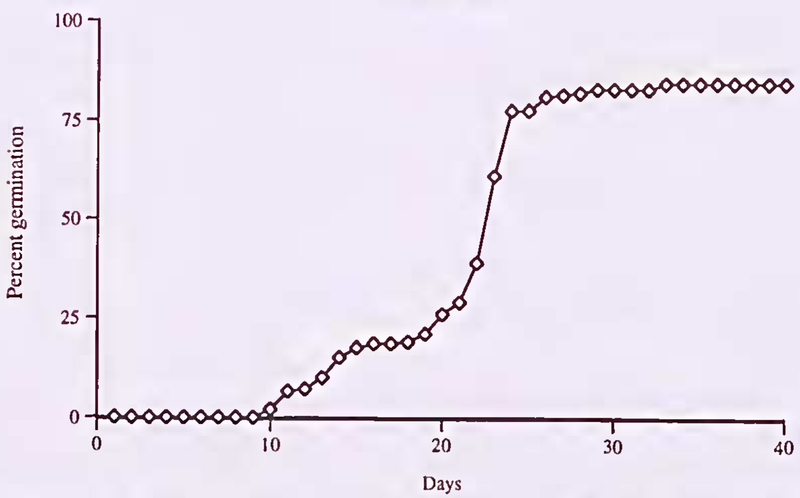


Figure 3. Graphic representation of patterns of germination. Pattern 1 typical of all species tested (see text) except *Calothamnus* spp. which conformed to Pattern 2.

Pattern 1 shows an exponential rise in the percentage of germinants reaching an asymptote earlier rather than later, whereas the shape depicted in Pattern 2 appears sigmoidal. The former pattern was evident for all species tested except *C. rupestris* and *C. quadrifidus*, in which cases germination followed the second pattern.

DISCUSSION

The species tested exhibited large differences between characteristics in reproductive units. For example, the mass of fruit between species ranged from 0.07 g for *Eucalyptus wandoo* to 13.9 g for *E. calophylla*. Similarly, the mass of seed within individual fruit ranged from less than 0.001 g for *E. platypus* and *E. wandoo* to 0.410 g for *E. calophylla*, and the number of seed in each fruit from 0.05 and 0.35 in *E. calophylla* to greater than 100 in *C. rupestris*. Differences within species were also noted. Replication of differences within species, between sites, in association with comparisons of variables from the sites where species were collected, may provide some insight into the cause of these differences.

Seeds and their inherent germination requirements have the potential to be as varied and unusual as the plants themselves (Bell 1994, Dixon and Meney 1994). At least a third of the flora in native habitat regions of south-western Australia are unable to germinate without some form of germination cue (*ibid*). In this study, percent viability and germinability of the species tested were both sufficiently high, suggesting that pre-treatment of seeds prior to germination is not vital to their regeneration. However, this does not negate the fact that pre-treatment may, indeed, enhance their regeneration, and may be the subject of future testing.

Overall, the results presented above suggest that pollination had occurred in remnant, revegetated and regenerated sites that were surveyed during this study. Pollinators visited the species tested and successful pollination occurred as inferred from the viability and germinability of seed. Furthermore, there appeared to be no differences in these attributes between sites.

We which to emphasize that our results do not provide conclusive proof that specific pollinators are responsible for seed set. This would require detailed experimental work, well beyond the scope of the present study. Rather, we simply record that plant species with a wide pollinator array were visited by generalist bird species, and pollination of these plant species appears to ensure seed banks potentially capable of sustaining populations.

PART 4: THE VALUE OF UNDERSTOREY

INTRODUCTION

A common method used in revegetation has been to plant as many trees as possible, often in rows of conspecifics, with little regard for the understorey (Murphy and Dalton 1997). Some of the reasons for this practice include creating shelter belts for the well-being of stock and minimizing erosion, particularly in wind-swept areas. In addition, planting trees contributes towards lowering of the water table and thereby decreasing problems of salinity. However, choice of plant species for revegetation must also consider the habitat requirements for potential pollinators.

This satellite study aimed to determine if revegetation with understorey attracted more pollinators than revegetation without understorey. An obligate bird pollinated species and an obligate insect pollinated species were used to examine what effect the establishment of understorey might have on bird and insect pollinator activity. Revegetation by Main Roads Western Australia in 1990 provided the opportunity to test this hypothesis in revegetation that was at least eight years old and, therefore, relatively established.

METHODS

A section of road between Gidgegannup and Toodyay (see Figure 1) had dense understorey with mid- and high-canopy species on the west side (hereafter referred to as the diverse site) (Photo 7), and a monoculture of *Acacia saligna* on the east side of the road (hereafter referred to as the wattle site) (Photo 8). Revegetation on both sides of the road extended up to 300 m long and no more than 30 m at the widest. Three observation sites approximately 20 m apart, were marked on either side of the road. On three mornings of four non-consecutive weeks, as soon after dawn as possible, instantaneous bird counts were conducted for 20 minutes from each of the six sites, with six volunteers rotating through each site. This rotation was repeated with a further 20 minutes at each site, totaling four hours of observations each morning when observations were conducted. All birds present within a 15 m radius of each site were noted and their activities recorded. Birds were noted if they were in the area of the canopy or if they were in the understorey layer. Although every attempt was made by individuals not to count the same bird twice, birds were inevitably counted more than once as observers moved from site to site.

After the first week, six patches of understorey were introduced on both sides of the road with one patch at each of the observation sites. Each patch consisted of 12 Mangles Kangaroo Paw (*Anigozanthos manglesii* subsp. *manglesii*), an obligate bird pollinated plant, and eight Yellow-eyed Flame Pea (*Chorizema dicksonii*), an obligate insect pollinated plant. Distribution of species within the patches were randomly set and were consistent for all patches.

Observations continued for a further 2 weeks with the artificial patches in place and then for a further week once the artificial patches had been removed.

Thus, the design of the observations was:

	Introduced understorey	Flowering of *Acacia saligna*
Week 1 (3 sessions)	absent	not flowering
Week 2 (3 sessions)	present	not flowering
Week 3 (3 sessions)	present	flowering
Week 4 (2 sessions)	absent	flowering

RESULTS

Overall, 1951 birds were observed during the four weeks of observations, with 21 species identified (Appendix 4). Of these, 1072 (55%) were honeyeaters: Brown Honeyeaters were by far the most numerous of all honeyeaters seen (N = 924, 86%), Singing Honeyeaters (N = 95) and White-cheeked Honeyeaters (N

= 49) collectively accounted for a further 13% of honeyeaters seen and two New Holland Honeyeaters and two Red Wattlebirds made up the rest of the honeyeaters.

An equal number of species (19) were seen on both sides of the road. However, differences included no New Holland Honeyeaters or Striated Pardalotes on the wattle site, and no Welcome Swallow or Shining Bronze-Cuckoo on the diverse site.

More birds were seen on the diverse site (N = 1295, 66%) and fewer (N = 656) in the stand of wattles (Table 10). In particular, honeyeaters (N= 777, 72%) favoured the diverse site over the wattle site (N = 295).

Overall, more birds were observed in the canopy on both sides of the road (diverse site = 939, wattle site = 579) than in the understorey (diverse site = 356, wattle site = 77). Similarly, more honeyeaters used the canopy than the understorey in both vegetation types (533 and 250 against 244 and 45 respectively).

The number of birds (or honeyeaters) did not differ significantly once the artificial understorey had been introduced, nor when the *Acacia saligna* was flowering with the artificial understorey in place, nor when the artificial patches had been removed (Table 10). Honeyeaters were the only bird species that foraged on the introduced understorey, and only on the *Anigozanthos manglesii*: no birds foraged from *Chorizema dicksonii* at any time (Table 11). Honeyeaters foraged more often on the introduced understorey on the wattle site than on the diverse site.

No quantitative or qualitative results of invertebrate activity are included due to the inability of most volunteers to accurately identify species to family or order.

DISCUSSION

The value of understorey is often assumed and it has only been recently that this value has been recognized (Seabrook 1994, Murphy and Dalton 1997, Thygesen 1998). For example, the presence of understorey plays a functional role in ecosystem structure, it increases floral diversity and, subsequently, faunal and invertebrate diversity, it provides habitat for shrub-foraging birds, provides habitat for low nesting species and it provides the cover required for many bird species to move within territories or in search of food, protection or nesting sites.

In this study, the methods of revegetation provided an opportunity to test, scientifically, if indeed birds, and particularly honeyeaters, preferentially utilize revegetation that has understorey, rather than revegetation that provides no understorey.

The results presented suggest that birds generally use vegetation that is made up of over- and mid-storey species in addition to having a well established understorey, rather than a monoculture with no understorey. The duration of the study did not allow for any conclusions to be reached in terms of whether an introduced understorey actually encouraged more birds or honeyeaters to the area. However, honeyeaters foraged from the introduced understorey more on the side devoid of shrub layer than on the side that had an established understorey. This is clear evidence that an understorey improves the food availability and habitat for honeyeaters. It would require long-term monitoring of a self-sufficient understorey to establish if honeyeaters

Table 10a. The numbers of birds and the number of honeyeaters seen on the diverse side and wattle side of Toodyay Road in relation to the introduction of an artificial understorey.

		Diverse site		Wattle site	
		All birds	Honeyeaters	All birds	Honeyeaters
Week 1	No Artificial understorey *Acacia saligna* not flowering	426	189	191	92
Week 2	Introduced understorey *Acacia saligna* not flowering	325	149	212	97
Week 3	Introduced understorey *Acacia saligna* flowering	237	181	130	64
Week 4	Artificial understorey removed *Acacia saligna* flowering	307	258	123	42

Table 10b. Differences between the number of birds and the number of honeyeaters seen on the diverse side and wattle side of Toodyay Road in relation to the introduction of an artificial understorey (see text for details).

	Diverse site		Wattle site	
	All birds	Honeyeaters	All birds	Honeyeaters
Wk 1 : Wk 2	$F_{1,44}$ = 0.166, *P*= 0.686	$F_{1,8}$ = 0.421, *P*= 0.842	$F_{1,44}$ = 0.039, *P*= 0.854	$F_{1,8}$ = 0.003, *P*= 0.958
Wk 1 : Wk 3	$F_{1,44}$ = 0.543, *P*= 0.465	$F_{1,8}$ = 0.001, *P*= 0.972	$F_{1,44}$ = 0.424, *P*= 0.518	$F_{1,8}$ = 0.117, *P*= 0.741
Wk 1 : Wk 4	$F_{1,44}$ = 0.161, *P*= 0.690	$F_{1,8}$ = 0.068, *P*= 0.801	$F_{1,44}$ = 0.584, *P*= 0.449	$F_{1,8}$ = 0.521, *P*= 0.491
Wk 2 : Wk 4	$F_{1,44}$ = 0.004, *P*= 0.948	$F_{1,8}$ = 0.182, *P*= 0.681	$F_{1,44}$ = 0.821, *P*= 0.370	$F_{1,8}$ = 0.427, *P*= 0.532
Wk 2 : Wk 3	$F_{1,44}$ = 0.145, *P*= 0.705	$F_{1,8}$ = 0.023, *P*= 0.884	$F_{1,44}$ = 0.60, *P*= 0.428	$F_{1,8}$ = 0.122, *P*= 0.736

Photo 1. Remnant vegetation adjacent to wheat field, Ajana, Kalbarri. (Location 1, Figure 1)

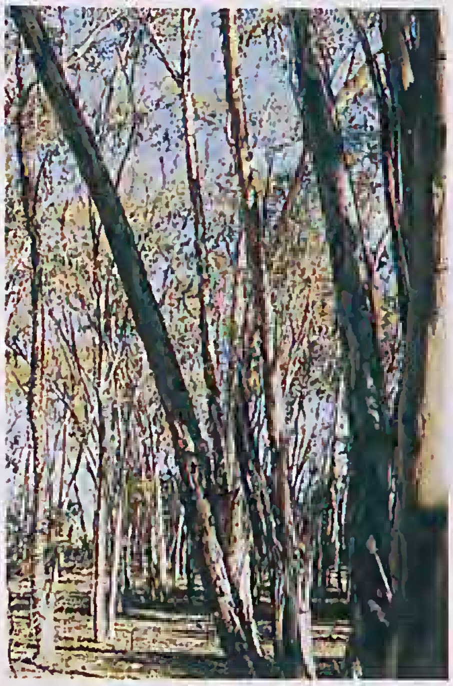


Photo 2. Remnant of mixed eucalyptus species, Merredin. (Location 6, Figure 1)

Photo 3. "Ribbons of Green" revegetation, Geraldton. (Location 2, Figure 1)

Photo 4. Volunteer (Vivienne Wells) surveying road verge fauna, North Dandelup. (Location 11, Figure 1)

Photo 5. Volunteer (Graeme Rhind) collecting fruit, Cranbrook. (Location 22, Figure 1)

Photo 6. Volunteers (Graeme Rhind, Meri Hitchins and Anne Peachey) licking closed and labelling envelops containing collected fruit, Cranbrook. (Location 22, Figure 1)

Photo 7. Volunteers (Michelle Davies, Kim Bendsten, Claire Stevenson, Wayne Clarke, Lyn Simmons, Diane Ross) at understorey study site, Toodyay Road. (Location 7, Figure 1)

Photo 8. Monoculture of *Acacia saligna*, Toodyay Road. (Location 7, Figure 1)

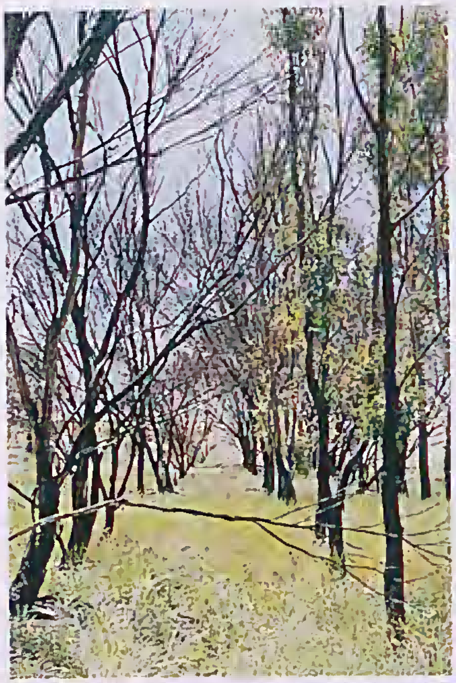


Photo 9. Stand of mixed, revegetated eucalyptus species at Pingelly (Figure 1), 14 months following fire.

Photo 10. Basal regrowth of *Eucalyptus loxophleba* at Pingelly (Figure 1), 14 months following fire.

Photo 11. *Eucalyptus platypus* seedlings at Pingelly (Figure 1), 14 months following fire.

Table 11. The number of birds seen foraging at the introduced understorey.

			Diverse site		Wattle site	
			Number of birds	Species	Number of birds	Species
Week 2	Day 1	*Anigozanthos manglesii*	1	1 Brown Honeyater	0	
		Chorizema dicksonii	0		0	
	Day 2	*Anigozanthos manglesii*	1	1 Brown Honeyater	7	4 Brown Honeyeater, 3 Singing Honeyeater
		Chorizema dicksonii	0		0	
	Day 3	*Anigozanthos manglesii*	2	2 Brown Honeyater	15	14 Brown Honeyeater, 1 Singing Honeyeater
		Chorizema dicksonii	0		0	
Week 3	Day 1	*Anigozanthos manglesii*	0		0	
		Chorizema dicksonii	0		0	
	Day 2	*Anigozanthos manglesii*	0		3	3 Brown Honeyater
		Chorizema dicksonii	0		0	
	Day 3	*Anigozanthos manglesii*	0		3	3 Brown Honeyater
		Chorizema dicksonii	0		0	
		Total number of birds	4		28	

are preferentially attracted to revegetation incorporating all strata of vegetation rather than revegetation without understorey. Insect pollinated plants, such as *Chorizema dicksonii* would need to be in place for longer than the short period of this study to provide more than a short-term refugia for invertebrates. Similarly, a long-term study would establish if invertebrates are more attracted to revegetation with, or without, understorey and subsequently if this invertebrate resource would attract birds that include invertebrates in their diets.

PART 5: REGENERATION FOLLOWING FIRE

INTRODUCTION

The nature and regenerative potential of Western Australian flora result from its long association with the substrate and with the natural elements. One such natural element, namely fire, has a high probability of occurrence in the south-west landscapes of Western Australia. Post-fire response of plants include obligate seeder species that recruit solely from seed after fire, and resprouter species that survive successive fires by resprouting from fire-resistant stems or root stocks (Baskin and Baskin 1998). Thus, species selection for regeneration should consider regenerative potential in terms of possible exposure to fire.

On a farm near Pingelly (32'54" S, 117'08" E) (Figure 1), at least two paddocks had been revegetated with mixed stands of eucalypts; one in 1984 and one in 1988. A small reserve on the farm, Moorumbine Reserve, consisted of wandoo woodland. In December 1997, an intense wildfire which originated in Brookton, 25 km NNW of Pingelly, burned the two paddocks and part of the wandoo woodland (Photo 9). As neither paddock had been burnt since planting, and Moorumbine Reserve had not been burnt for at least 50 years (F. Leake pers. comm.), this afforded the opportunity to assess the regenerative potential of up to eleven species of eucalypt that had been simultaneously exposed to fire. It also allowed assessment of the survival of seedlings and regrowth after their first summer.

METHODS

One year after the fire (November 1998), and before summer, regrowth of up to ten species of eucalypts were assessed in the two paddocks that were burned, and of *Eucalyptus wandoo* in the wandoo woodland. All trees selected were marked with flagging tape and aluminium tags for future reference. The numbers of seedlings in 1m x 1m quadrats on the north and south side of the base of each marked tree were counted and combined.

Nine species of eucalypts were monitored in Paddock 1, namely *Eucalyptus astringens, E. camaldulensis, E. cladocalyx, E. gardneri* subsp. *gardneri, E. loxophleba* subsp. *loxophleba, E. nutans, E. platypus, E. sargentii and E. spathulata*. Four species were monitored in Paddock 2, namely, *E. kondininensis, E. loxophleba, E. platypus* and *E. sargentii*. *Eucalyptus kondininensis* was the only species of the four absent from Paddock 1.

Not all of Moorumbine Reserve was burnt. Therefore, there were a limited number of *E. wandoo* which could be included in the observations. Furthermore, *E. wandoo* typically regenerates in ashbeds (Burrows *et al.* 1990). Thus, the regeneration of *E. wandoo* was tested by counting seedlings in a 10 m x 1 m transect spanning one ash-bed within the Reserve.

Five months later (March 1999), after summer, all observations were repeated to determine survival of seedlings and basal and epicormic regrowth following the hot, dry summer months.

RESULTS

Of the nine species of eucalypts in Paddock 1, six species (*E. astringens*, *E. gardneri*, *E. nutans*, *E. platypus*, *E. sargentii* and *E. spathulata*) reseeded rather than resprouted and one *E. cladocalyx* tree produced one seedling (Table 12). All *E. cladocalyx* resprouted, as did *E. camaldulensis* and most *E. loxophleba*. Of the latter three, *E. camaldulensis* exhibited epicormic regrowth and no basal regrowth, *E. cladocalyx* displayed both basal and epicormic growth, whereas *E. loxophleba* demonstrated more basal than epicormic regrowth (Photo 10). Nevertheless, all regrowth, both basal and epicormic, survived the summer and, indeed, flourished. Of the species in which regeneration was predominantly by reseeding rather than resprouting, survival of seedlings over the summer was 100%. Moreover, more seedlings were evident in March 1999 than in November 1998, indicating continued germination in the year after the fire. One exception was *E. spathulata* in which the survival of seedlings was relatively low (33.5%).

For the species common to Paddocks 1 and 2, regenerative strategies were generally similar. For example, *E. loxophleba* resprouted more from the base than epicormically and no seedlings were apparent under the trees marked, and *E. platypus* and *E. sargentii* did not resprout. Both *E. sargentii* and *E. platypus* reseeded. Interestingly, neither species had any seedlings visible in November 1998, yet seedlings were evident for both species by March 1999; many more seedlings were visible for *E. sargentii* than *E. platypus* after the summer in Paddock 1 and the reverse was true in Paddock 2, in which many more *E. platypus* than *E. sargentii* seedlings became exposed after the summer (Photo 11). *E. kondininensis* did not show any signs of resprouting or reseeding in November 1998 or in March 1999.

There was no basal regrowth but scant epicormic regrowth evident in some *Eucalyptus wandoo* that were burnt in Moorumbine Reserve. In light of the different methods of assessment, seedling survival of *E. wandoo* following the summer (69%) was not as great as that in most reseeder species monitored in Paddock 1 (up to 100% for *E. gardneri*).

DISCUSSION

Many compounding issues dictate the degree of regeneration of species burnt in a wildfire. Some of these influences include the interval between fires, the intensity of individual fires, the condition of the substrate at the time of the fire and subsequent weather post fire, with particular reference to rainfall (Gill 1975, Bond and van Wilgen 1996). As noted above, the paddocks burnt during the intense wildfire near Pingelly in December 1997 had not been burnt since revegetation 13 and 9 years previously, and Moorumbine Reserve had not been burnt for at least 50 years. Rainfall for the immediate area has been 406 mm per annum (N = 49). From 1984 to 1999, 1994 recorded the lowest annual rainfall, with 286 mm, and 1996 the highest, with 474 mm (Table 13). Rainfall from November

Table 12a. The number of seedlings and the presence of basal and epicormic growth in eucalyptus species in November 1998 and March 1999 in Paddock 1, Pingelly (see text for details). Sample sizes and the percentage seedling survival over these months are included.

	November 1998				March 1999				Percentage seedling survival
	Sample size	Number of trees with			Sample size	Number of trees with			Mean ± s.e.
		seedlings	basal regrowth	epicormic regrowth		seedlings	basal regrowth	epicormic regrowth	
Eucalyptus astringens	10	9	0	0	10	9	0	0	88.7 ± 18.3
Eucalyptus camaldulensis	10	0	0	10	10	0	0	10	-
Eucalyptus cladocalyx	10	1	10	10	10	0	10	10	-
Eucalyptus gardneri	10	10	0	0	10	8	0	0	203.2 ± 92.9
Eucalyptus loxophleba	10	0	9	3	10	0	10	3	-
Eucalyptus nutans	3	2	0	0	3	2	0	0	129.2 ± 4.2
Eucalyptus platypus	4	2	0	0	3	1	0	0	75.0 ± 75.0
Eucalyptus sargentii	9	8	0	0	10	9	0	0	88.8 ± 19.1
Eucalyptus spathulata	10	6	0	0	10	4	0	0	33.5 ± 15.7

Table 12b. The number of seedlings and the presence of basal and epicormic growth in eucalyptus species in November 1998 and March 1999 in a) Paddock 2 and b) in one 10 m x 1 m transect in Moorumbine Reserve (see text for details). Sample sizes and the percentage seedling survival over these months are included.

a) Paddock 2	November 1998				March 1999				Percentage seedling survival
	Sample size	Number of trees with			Sample size	Number of trees with			Mean ± s.e.
		seedlings	basal regrowth	epicormic regrowth		seedlings	basal regrowth	epicormic regrowth	
Eucalyptus kondininensis	10	0	0	0	10	0	0	0	-
Eucalyptus loxophleba	10	0	9	6	10	0	10	6	-
Eucalyptus platypus	10	0	0	0	10	5	0	0	-
Eucalyptus sargentii	10	0	0	0	10	1	0	0	-

b) Moorumbine Reserve - *Eucalyptus wandoo* (10m x 1 m transect)

metres	Number of seedlings November 1998	Number of seedlings March 1999	Percentage seedling survival
0 to 1	2	2	100.0
1 to 2	4	4	100.0
2 to 3	2	1	50.0
3 to 4	3	3	100.0
4 to 5	3	2	66.7
5 to 6	3	3	100.0
6 to 7	0	0	
7 to 8	2	0	0.0
8 to 9	2	1	50.0
9 to 10	4	2	50.0
Total	25	18	mean ± s.e. 68.5 ± 11.6

Table 13. Monthly rainfall (mm) near Pingelly from 1984 to 1999.

	1984	1985	1986	1987	1988	1989	1990	1991	1992
January	0.0	0.3	5.0	0.0	0.0	12.0	110.5	2.8	0.3
February	6.5	9.3	55.5	0.0	0.0	25.0	24.0	27.5	49.5
March	39.8	9.5	18.5	6.0	4.3	0.0	15.0	10.8	22.0
April	52.3	39.0	1.0	37.0	27.5	41.8	34.8	35.0	46.0
May	84.8	20.8	60.8	51.0	66.3	66.5	38.5	19.3	17.3
June	39.5	41.5	104.5	45.0	89.5	56.0	29.3	78.8	109.8
July	35.3	99.3	47.8	95.0	70.8	49.0	94.3	101.8	40.3
August	46.3	54.5	65.5	42.5	33.3	36.8	26.5	49.5	72.5
September	76.0	27.8	18.3	33.0	46.3	21.5	28.0	30.8	47.3
October	12.8	13.5	8.0	9.5	23.3	28.5	17.5	16.5	9.0
November	36.0	16.0	33.5	28.3	10.3	2.0	2.0	32.0	38.3
December	7.0	0.0	3.3	30.8	23.8	0.0	0.3	19.8	5.0
Total	436.0	331.3	421.5	378.0	395.0	339.0	420.5	424.3	457.0

	1993	1994	1995	1996	1997	1998	1999	Mean monthly rainfall (1950 - 1999) Mean ± s.e.
January	0.0	0.0	8.8	0.8	0.5	0.0	17.3	9.7 ± 3.2
February	45.5	5.0	2.5	0.8	21.8	0.0	0.0	19.0 ± 4.4
March	15.0	0.0	3.8	5.8	67.8	21.0	30.8	14.9 ± 2.9
April	8.0	0.0	13.0	19.8	19.3	28.0	8.8	26.6 ± 3.4
May	47.8	90.3	62.5	31.8	39.3	30.0	68.5	53.0 ± 4.3
June	73.8	54.3	61.8	106.8	39.5	96.0	67.3	79.5 ± 5.3
July	36.8	53.5	97.0	136.0	45.5	41.5	80.0	70.1 ± 5.2
August	63.0	44.0	22.3	53.0	76.0	90.5	56.0	50.6 ± 4.0
September	53.3	23.5	31.8	45.0	49.0	36.5		33.5 ± 2.1
October	5.8	10.8	59.3	33.0	22.3	18.3		22.7 ± 2.3
November	40.8	3.0	3.3	41.8	4.5	14.3		16.0 ± 1.9
December	1.5	1.8	15.5	0.0	0.0	18.8		11.1 ± 2.0
Total	391.0	286.0	381.3	474.3	385.3	394.8		

1998 to March 1999 was not consistent with mean values. For example, November 1998 rainfall was similar to mean rainfall for November, February was particularly low in comparison, whereas December, January and March were higher in comparison to mean values for those months (Table 13). Therefore, regeneration and survival of seedlings and regrowth from November 1998 to March 1999 may be peculiar to this pattern of rainfall, and any other pattern might not have produced a similar result.

Strategies adopted by different species result from their long exposure to local environmental conditions. A majority of the species in Paddocks 1 and 2 were obligate reseeders that recruit solely from seed. A major disadvantage in these species would be the occurrence of fires with intervals less than the time required for them to establish adequate seed banks (Muir 1987). Without seed banks, these species would be unable to regenerate after the fire and would become locally extinct (Wellington 1989). On the other hand, species that survive fires by resprouting from stems or root stocks would more likely be able to survive successive fires. Thus, if another fire had scorched the paddocks during the summer, it is more likely that *E. loxophleba, E. camaldulensis and E. cladocalyx* would have resprouted after time and survived, whereas the reseeders, having depleted their seed stores during the first regenerative attempt, would not have reserves with which to regenerate after a summer fire. *Eucalyptus camaldulensis* occurs Australia-wide and *E. cladocalyx* originates from South Australia; the remaining species in Paddocks 1 and 2, and *E. wandoo*, are endemic to Western Australia. Interestingly, of the resprouters that would survive frequent fires, two are not local to Western Australia. In the event of successive fires with inadequate intervals for reseeders to establish adequate seed banks, the species endemic to Western Australia may be eliminated, whereas non-local resprouters would survive. Thus, when selecting species for regeneration, the use of native local resprouters should be encouraged to ensure the most likely success in regeneration, given the possibility of fires.

The requirements of specific species may also need to be considered when selecting species for regeneration. For example, *E. kondininensis* typically grows on salty flats adjacent to salt lakes (Brooker and Kleinig 1990). As there were no salt lakes nearby, the fact that there was no regrowth or seedlings for this species may indicate that the location was inappropriate. However, the intensity of the fire may have been so great that any seeds were scorched and, therefore, unable to regenerate.

For at least three species, namely *E. gardneri*, *E. sargentii* and *E. platypus*, observations made of seedlings of trees not marked indicated large numbers of seedlings that regenerated during the summer months. This scenario is apparently typical of mallets (Steve Hopper unpubl.).

PART 6: GENERAL CONCLUSIONS

Escalating amounts of both money and time continue to be devoted to regeneration in the south west of Western Australia, principally to combat rising water tables and associated salinity (Brandenburg and Majer 1995). Irrespective of the original intent of restoration activity, the success of the operation includes the re-establishment of all functional units within the ecosystem. Following a study of fragmented forests, Aizen and Feinsinger (1994) suggested that pollination and seed set may be useful indicators of ecosystem health.

The information gained from this community-based study suggests that generalist pollinators were present in both remnant and revegetated areas in the south west of Western Australia, and that pollination was taking place. Indeed, seed viability and germinability were relatively high. The majority of species planted and, therefore, the most frequently visited species were eucalypts.

Pollinators are likely to be attracted more to revegetation which has diverse species covering high-, mid- and understoreys than to monocultures with no understorey. Thus, restoration techniques should select for a variety of native local species to create enhanced diversity. Having established the return of the generalist species, efforts may then be extended towards catering for the specialist species. This way, a more complex ecosystem would be attained. Furthermore, native local resprouters are more likely to succeed following fire than reseeders, given the high probability of fire in the south-western landscapes.

Many remnants and revegetated patches are isolated within agricultural farmlands (Yates and Hobbs 1997). Planting local provenance species in as natural configuration as possible may increase their resilience to disease and weed invasion (Gardiner and Midgley 1994, Coates and van Leewen 1997). The threat of such disturbances applies to both revegetated and remnant areas (Yates and Hobbs 1997). With informed planning, it is hoped that the regenerative powers within remnant patches and the self-sustainability in remnant and revegetated areas will be sufficient so that human resources can be directed towards other areas in urgent need of restoration. However, we wish to emphasize that much more needs to be learnt about the restoration ecology of south-west Australian vegetation. The return of a few generalist species to the landscape as documented in this study is a very small step towards restoring the megadiverse communities that originally occupied these ancient lands. It is clear that self-replacement over large areas as has occurred in post-glacial Europe and North America is most unlikely in the south-west for all but a few generalist species. In this context, the importance of protecting all the remains of native vegetation in the south-west in evident, indeed, paramount. Such remnants will provide the vital sources of local seed and cuttings essential for restoring the incredibly complex and highly localised biodiversity for which the south-west has become world famous.

ACKNOWLEDGEMENTS

We wish to thank the Gordon Reid Foundation for Conservation for funding the project and all the volunteers who gladly gave of their time. These include:

Anne Peachey, Anthony Bougher, Archie and Thelma Jackson, Barbara Anderson, Barbara Payne, Beth Gaze, Bob and Pat Horwood, Buddy Kent, Cameron Pidgeon, Claire Stevenson, Cyrus Naseri, Danielle Jose, Dawn Attwell, Dee Iriks, Desrae and Wayne Clarke, Diane Ross, Felicity Leake, Fran Alcock, Frank Turnbull, Franscisco Tovar, Freda Blakeway, George and Jose Schmidt, George and Pam Allen, Graeme Rhind and Meri Hitchins, Grant Wells, Heather Adamson, Helen Pierce, Jacinta Christie, Jackie Forrest, Jan Grey, Jay Humphries, Jessica Jakubanis, John Byers, Joyce and John White, Julie Barnes, Karen Hurley, Kath Mathwin, Kim Bendsten, Lauren Flinn, Leanne McRoberts, Leon Sylvester, Lyn Simmons, Master Gardener Volunteers, Kings Park and Botanic Gardens, Michelle Davies, Neil Harmon, Nicole Longhi, Nicole Woodland, Olga Green, Penney Mossop, Penny London, Ray Paynter, Ray Watson, Renee Morphett, Rod Smith, Steve McCabe, Suan and Bonnie Goei and kids, Terri Lloyd, Valerie Spence, Vera Patterson, Vivien Wells, Vivienne Dare, Walter Kolb, Wendy Porter and Marty Tinney, Wesley Bancroft, Zoe Benham.

REFERENCES

ADKINS, S.W. and BELLAIRS, S.M. 1997. Seed dormancy mechanisms in Australian native species. pp. 81-91. *In: Proceedings from the second Australian workshop on native seed biology for revegetation.* S.M. BELLAIRS and J.M. OSBORNE (eds.) Australian Centre for Minesite Rehabilitation Research, Queensland.

AIZEN, M.A. and FEINSINGER, P. 1994. Forest fragmentation: pollination and plant reproduction in a Chaco dry forest, Argentina. *Ecology* 75: 330-351.

ARMSTRONG, D.P. 1991. Nectar depletion and its implications for honeyeaters in heathland near Sydney. *Australian Journal of Ecology* 16: 99-109.

ARNOLD, G.W. and WEELDENBURG, J.R. 1998. The effects of isolation, habitat fragmentation and degradation by livestock grazing on the use by birds of patches of Gimlet *Eucalyptus salubris* woodland in the wheatbelt of Western Australia. *Pacific Conservation Biology* 4: 155-163.

BASKIN, C.C. and BASKIN, J.M. 1998. *Seeds. Ecology, biography, and evolution of dormancy and germination.* Academic Press, San Diego.

BEARD, J.S. 1990. *Plant life of Western Australia.* Kangaroo Press Pty Ltd., Kenthurst, New South Wales.

BELL, D.T. 1994. Seed germination ecology in Western Australia: lessons for the mining industry. pp. 5-14. *In: Proceedings of National Workshop on Native Seed Biology for Revegetation.* S.M. BELLAIRS and L.C. BELL (eds.) Australian Centre for Minesite Rehabilitation Research, Queensland and The Chamber of Mines and Energy of Western Australia Inc., Western Australia.

BELL, D.T. 1999. Turner Review No. 1. The process of germination in Australian species. *Australian Journal of Botany* 47: 475-517.

BENNET, E.M. 1993. *Common and Aboriginal names of Western Australian plant species. Second edition.* Wildflower Society of Western Australia. Eastern Hills Branch, Glen Forrest, Western Australia.

BOND, W.J. and VAN WILGEN, B.W. 1996. *Fire and plants.* Chapman and Hall, London.

BRANDENBURG, S.A. and MAJER, J.D. 1995. A database for revegetated areas in the Tammin region of Western Australia: implications for land owners, managers and researchers. pp. 258-270. *In: Nature Conservation 4: the role of networks.* D.A. SAUNDERS, J.L. CRAIG and E.M. MATTISKE (eds.) Surrey Beatty & Sons, NSW, Australia.

BROOKER, M.I.H. and KLEINIG, D.A. 1990. *Field guide to Eucalypts. South-western and South Australia.* Inkata Press, Melbourne.

BROWN, E.D. and HOPKINS, M.J.G. 1996. How New Guinea rainforest flower resources vary in time and space: implications for nectarivorous birds. *Australian Journal of Ecology* 21: 363-378.

BROWN, E.M., BURBIDGE, A.H., DELL, J., EDINGER, D., HOPPER, S.D. and WILLS, R.T. 1997. *Pollination in Western Australia: a database of animals visiting flowers.* Handbook No.15, WA Naturalists' Club, Perth.

BURROWS, N., GARDINER, G., WARD, B. and ROBINSON, A. 1990. Regeneration of *Eucalyptus wandoo* following fire. *Australian Forestry* 53: 248-258.

CARTHEW, S.M. and GOLDINGAY, R.L. 1997. Non-flying mammals as pollinators. *Trends in Ecology and Evolution* 12: 104-108.

CHRISTIDIS, L. and BOLES, W.E. 1994. *The taxonomy and species of birds of Australia and its territories.* Royal Australasian Ornithologists Union. Monograph 2. Royal Australasian Ornithologists Union, Victoria.

COATES, D.J. and VAN LEEWIN, S.J. 1997. Delineating seed provenance areas for revegetation from patterns of genetic variation. pp. 3-14. *In: Proceedings from the second Australian workshop on native seed biology for revegetation.* S.M. BELLAIRS and J.M. OSBORNE (eds.) Australian Centre for Minesite Rehabilitation Research, Queensland.

COLLINS, B.G., GREY, J. and MCNEE, S. 1990. Foraging and nectar use in nectarivorous bird communities. *Studies in avian biology* 13: 110-122.

DIXON, K.W. and MENEY, K.A. 1994. Seed quality for minesite rehabilitation. pp. 15-19. *In: Proceedings of National Workshop on Native Seed Biology for Revegetation.* S.M. BELLAIRS and L.C. BELL (eds.) Australian Centre for Minesite Rehabilitation Research, Queensland and The Chamber of Mines and Energy of Western Australia Inc, Western Australia.

EHRLICH, P.R. and MURPHY, D.D. 1987. Monitoring populations on remnants of native vegetation. pp. 201-210. *In: Nature conservation. The role of remnants of native vegetation.* D.A. SAUNDERS, G.W. ARNOLD, A.A. BURBIDGE and A.J.M. HOPKINS (eds.). Surrey Beatty & Sons New South Wales.

FORD, H.A. and PATON, D.C. 1982. Partitioning of nectar sources in an Australian honeyeater community. *Australian Journal of Ecology* 7: 149-159.

GARDINER, C.A. and MIDGLEY, S.J. 1994. The importance of seed quality in successful revegetation programs. pp. 33-40. *In: Proceedings of National Workshop on Native Seed Biology for Revegetation.* S.M. BELLAIRS and L.C. BELL (eds.) Australian Centre for Minesite Rehabilitation Research, Queensland and The Chamber of Mines and Energy of Western Australia Inc, Western Australia.

GILL, A.M. 1975. Fire and the Australian flora: a review. *Australian Forestry* 28: 4-25.

GRIEVE, B.J. and BLACKALL, W.E. 1975. *How to know Western Australian wildflowers. A key to the flora of the extratropical regions of Western Australia. Part IV.* University of Western Australia Press, Perth.

GRIEVE, B.J. 1980. *How to know Western Australian wildflowers. A key to the flora of the extratropical regions of Western Australia. Part IIIA. Second edition.* University of Western Australia Press, Perth.

GRIEVE, B.J. 1981. *How to know Western Australian wildflowers. A key to the flora of the extratropical regions of Western Australia. Part IIIB. Second edition.* University of Western Australia Press, Perth.

GRIEVE, B.J. 1988. *How to know Western Australian wildflowers. A key to the flora of the extratropical regions of Western Australia. Part I. Second edition.* University of Western Australia Press, Perth.

GRIEVE, B.J. 1998. *How to know Western Australian wildflowers. A key to the flora of the extratropical regions of Western Australia. Part II. Second edition.* University of Western Australia Press in association with the Wildflower Society of Western Australia (Inc.), Perth.

HOBBS, R.J. 1993. Effects of landscape fragmentation of ecosystem processes in the Western Australian wheatbelt. *Biological Conservation* 64: 193-201.

KEAST, A. 1968. Seasonal movements in the Australian honeyeaters (Meliphagidae) and their ecological significance. *Emu* 67: 159-209.

KEAST, A., RECHER, H.F., FORD, H. and SANDERS, D. 1985. *Birds of eucalypt forests and woodlands: ecology, conservation, management.* Royal Australasian Ornithologists Union and Surrey Beatty and Sons.

LADD, P.G. and CONNELL, S.W. 1994. Andromonoecy and fruit set in three genera of the Proteaceae. *Botanical Society of the Linnean Society.* 116: 77-88.

MUIR, B.G. 1987. Time between germination and first flowering of some perennial plants. *Kingia* 1: 75-83.

MURPHY, R.G. and DALTON, G.S. 1997. Understorey establishment research. pp. 143-148. *In: Proceedings from the second Australian workshop on native seed biology for revegetation.* S.M. BELLAIRS and J.M. OSBORNE (eds.) Australian Centre for Minesite Rehabilitation Research, Queensland.

NEAL, P.R. 1998. Pollinator restoration. *Tree* 13: 132-133.

NEWBEY, B. 1999. *Birds on Farms Project in Western Australia* 1996 - 1999. Western Australian Bird Notes. Suppl. No. 5. Birds Australia - WA Group, Floreat, Western Australia.

PATON, D.C. 1982. The influence of honeyeaters on the flowering strategies of Australian plants. pp. 95-108. *In: Pollination and evolution.* J.A. ARMSTRONG, J.M. POWELL, and A.J. RICHARDS (eds.) Royal Botanic Gardens Sydney.

PATON, D.C. 1985. Food Supply, Population Structure, and Behaviour of New Holland Honeyeaters *Phylidonyris novaehollandiae* in Woodland near Horsham, Victoria. pp. 219-230. *In: Birds of Eucalypt Forests and Woodlands: Ecology, Conservation and Management.* A. KEAST, H.F. RECHER, H.A. FORD AND D. SAUNDERS (eds.). Royal Australasian Ornithologists Union and Surrey Beatty, Sydney.

PATON, D.C. 1988. Interdependence of Australian honeyeaters (Meliphagidae) and nectar-producing plants. pp. 549-559. *In: Acta XIX Congressus Internationalis Ornithologius, Ottawa.* H. OUELLET (ed.) National Museum of National Sciences. University of Ottawa Press, Ottawa.

PYKE, G.H. 1983. Seasonal pattern of abundance of honeyeaters and their resources in heathland areas near Sydney. *Australian Journal of Ecology* 8: 217-233.

PYKE, G.H., O'CONNOR, P.J. and RECHER, H.F. 1989. Relationships between nectar production and yearly and spatial variation in density and nesting of resident honeyeaters near Sydney. *Australian Journal of Ecology* 18: 221-229.

RATHCKE, B.J. and JULES, E.S. 1993. Habitat fragmentation and plant-pollinator interactions. *Current Science* 65: 273-277.

RECHER, H.F. and HOLMES, R.T. 1985. Foraging ecology and seasonal patterns of abundance in a forest avifauna. pp. 79-96. *In: Birds of eucalypt forests and woodlands: ecology, conservation, management.* A. KEAST, H.F. RECHER, H. FORD and D. SANDERS (eds.). Royal Australasian Ornithologists Union and Surrey Beatty and Sons.

ROTENBERRY, J.T. 1985. The role of habitat in avian community composition: physiognomy or floristics? *Oecologia* 67: 213-217.

SAFFER, V.M. 1998. *A comparison of foodplant utilization by nectar-feeding marsupials and birds in the Fitzgerald River National Park, Western Australia.* PhD Thesis, Murdoch University, Perth.

SAUNDERS, D.A., ROWLEY, I. and SMITH, G.T. 1985. The effects of clearing for agriculture on the distribution of cockatoos in the southwest of Western Australia. pp. 309-321. *In: Birds of eucalypt forests and woodlands: ecology, conservation, management.* A. KEAST, H.F. RECHER, H. FORD and D. SANDERS (eds.). Royal Australasian Ornithologists Union and Surrey Beatty and Sons.

SAUNDERS, D.A. and INGRAM, J.A. 1995. *Birds of Southwestern Australia. An atlas of changes in the distribution and abundance of the wheatbelt fauna.* Surrey Beatty & Sons, New South Wales.

SCHATRAL, A and OSBORNE, J.M. 1994. Seed biology of south west shrub species. pp. 33-40. *In: Proceedings of National Workshop on Native Seed Biology for Revegetation.* S.M. BELLAIRS and L.C. BELL (eds.) Australian Centre for Minesite Rehabilitation Research, Queensland and The Chamber of Mines and Energy of Western Australia Inc, Western Australia.

SEABROOK, J. 1994. *Growing understorey seed.* Greening Western Australia.

SIMPSON, B.B. and NEFF, J.L. 1983. Evolution and diversity of floral rewards. pp. 143-159. *In: Handbook of experimental pollination biology.* C.E. JONES and R.J. LITTLE (eds.). Scientific and academic editions, New York.

THYGESEN, J.A. 1998. Greening Western Australia sustainable seed banks project. pp. 141-143. *In: Managing our bushland: proceedings of a conference about the protection and management of urban bushland.* Urban Bushland Council WA Inc.

VAN LEEWIN, S.J. and LAMONT, B.B. 1996. Floral damage by animals and its impact on reproductive success in *Banksia tricuspis* Meisner (Proteaceae). pp. 196-202. *In: Gondwanan heritage: past, present and future of the Western Australian biota.* S.D. HOPPER, J.A. CHAPPILL, M.S. HARVEY and A.S. GEORGE (eds.) Surrey Beatty & Sons, New South Wales.

WELLINGTON, A.B. 1989. Seedling regeneration and the population dynamics of eucalypts. pp. 155-167. *In: Mediterranean landscapes in Australia: mallee ecosystems and their management.* J.C. NOBLE and R.A. BRADSTOCK (eds.) CSIRO, Melbourne.

WESTERN AUSTRALIAN HERBARIUM (1999). *FloraBase – Information on the Western Australian flora.* Department of Conservation and Land Management. (http://www.calm.wa.gov.au/science/florabase.html).

WHELAN, R.J. 1989. The influence of fauna on plant species composition. pp.

107-142. *In: Animals in primary succession: the role of fauna in reclaimed lands.* J.D. MAJER. (ed.) Cambridge University Press, Cambridge.

WILLS, R.T 1989. *Management of the flora utilised by the European honey bee in kwongan of the Northern Sandplain of Western Australia.* PhD Thesis, University of Western Australia, Perth.

WILLS, R.T., LYONS, M.N. and BELL, D.T. 1990. The European honey bee in Western Australian kwongan: foraging preferences and some implications for management. *Proceedings of the Ecological Society of Australia* 16: 167-176.

YATES, C.J. and HOBBS, R.J. 1997. Temperate eucalypt woodlands: a review of their status, processes threatening their persistence and techniques for restoration. *Australian Journal of Botany* 45: 949-973.

Appendix 1. Binomial and common names of birds, after Christidis and Boles 1994, recorded from all sites.

Family	Scientific name	Common name
Anatidae	*Chenonetta jubata*	Australian Wood Duck
Accipitridae	*Accipiter fasciatus*	Brown Goshawk
Columbidae	*Streptopelia senegalensis*	Laughing Turtle-Dove
	Phaps chalcoptera	Common Bronzewing
	Ocyphaps lophotes	Crested Pigeon
Cacatuidae	*Calyptorhynchus banksii*	Red-tailed Black-Cockatoo
	Calyptorhynchus latirostris	Short-billed Black-Cockatoo
	Cacatua roseicapilla	Galah
	Cacatua tenuirostris	Long-billed Corella
	Cacatua sanguinea	Little Corella
Psittacidae	*Trichoglossus haematodus*	Rainbow Lorikeet
	Glossopsitta porphyrocephala	Purple-crowned Lorikeet
	Polytelis anthopeplus	Regent Parrot
	Platycercus icterotis	Western Rosella
	Barnardius zonarius	Australian Ringneck
	Purpureicephalus spurius	Red-capped Parrot
	Neophema elegans	Elegant Parrot
Cuculidae	*Cuculus pallidus*	Pallid Cuckoo
	Chrysococcyx basalis	Horsfield's Bronze-Cuckoo
	Chrysococcyx lucidus	Shining Bronze-Cuckoo
Halcyonidae	*Dacelo novaeguineae*	Laughing Kookaburra
	Todiramphus sanctus	Sacred Kingfisher
Meropidae	*Merops ornatus*	Rainbow Bee-eater
Climacteridae	*Climacteris rufa*	Rufous Treecreeper
Maluridae	*Malurus splendens*	Splendid Fairy-wren
	Malurus lamberti	Variegated Fairy-wren
Pardalotidae	*Pardalotus punctatus*	Spotted Pardalote
	Pardalotus striatus	Striated Pardalote
	Sericornis frontalis	White-browed Scrubwren
	Smicrornis brevirostris	Weebill
	Gerygone fusca	Western Gerygone
	Acanthiza apicalis	Inland Thornbill
	Acanthiza inornata	Western Thornbill
	Acanthiza chrysorrhoa	Yellow-rumped Thornbill
Meliphagidae	*Anthochaera carunculata*	Red Wattlebird
	Anthochaera chrysoptera	Little Wattlebird
	Acanthagenys rufogularis	Spiny-cheeked Honeyeater
	Manorina flavigula	Yellow-throated Miner
	Lichenostomus virescens	Singing Honeyeater
	Lichenostomus leucotis	White-eared Honeyeater
	Lichenostomus cratitius	Purple-gaped Honeyeater
	Lichenostomus ornatus	Yellow-plumed Honeyeater
	Lichenostomus penicillatus	White-plumed Honeyeater
	Melithreptus brevirostris	Brown-headed Honeyeater
	Melithreptus lunatus	White-naped Honeyeater

Appendix 1. (continued).

Family	Scientific name	Common name
	Lichmera indistincta	Brown Honeyeater
	Phylidonyris novaehollandiae	New-Holland Honeyeater
	Phylidonyris nigra	White-cheeked Honeyeater
	Phylidonyris albifrons	White-fronted Honeyeater
	Acanthorhynchus superciliosus	Western Spinebill
Petroicidae	*Microeca fascinans*	Jacky Winter
	Petroica multicolor	Scarlet Robin
	Petroica goodenovii	Red-capped Robin
	Eopsaltria griseogularis	Western Yellow Robin
	Eopsaltria georgiana	White-breasted Robin
Pomatostomidae	*Pomatostomus superciliosus*	White-browed Babbler
Neosittidae	*Daphoenositta chrysoptera*	Varied Sittella
Pachycephalidae	*Pachycephala pectoralis*	Golden Whistler
	Pachycephala rufiventris	Rufous Whistler
	Colluricincla harmonica	Grey Shrike-thrush
Dicruridae	*Myiagra inquieta*	Restless Flycatcher
	Grallina cyanoleuca	Magpie-lark
	Rhipidura fuliginosa	Grey Fantail
	Rhipidura leucophrys	Willie Wagtail
Campephagidae	*Coracina novaehollandiae*	Black-faced Cuckoo-shrike
	Lalage sueurii	White-winged Triller
Artamidae	*Artamus cinereus*	Black-faced Woodswallow
	Artamus cyanopterus	Dusky Woodswallow
	Cracticus torquatus	Grey Butcherbird
	Cracticus nigrogularis	Pied Butcherbird
	Gymnorhina tibicen	Australian Magpie
Corvidae	*Corvus coronoides*	Australian Raven
Motacillidae	*Anthus novaeseelandiae*	Richard's Pipit
Dicaedae	*Dicaeum hirundinaceum*	Mistletoebird
Hirundinidae	*Hirundo neoxena*	Welcome Swallow
	Hirundo nigricans	Tree Martin
Zosteropidae	*Zosterops lateralis*	Grey-breasted White-eye

Appendix 2. Binomial and common names of plants, after Bennet 1993, recorded as flowering in all sites surveyed. * species not endemic to Western Australia.

Family		Genus	Species	Common Name
Amaranthaceae		*Ptilotus*	spp.	
Anacardiaceae	*	*Schinus*	*terebinthifolia*	
Bignoniaceae	*	*Tecoma*	*stans*	
Casuarinaceae		*Allocasuarina*	*acutivalvis*	
		Allocasuarina	*campestris*	
		Allocasuarina	*huegeliana*	Rock Sheoak
		Allocasuarina	sp.	
		Casuarina	*obesa*	Swamp Sheaok
		Casuarina	spp.	
Cupressaceae		*Actinostrobus*	*arenarius*	Sand Plain Cypress
Dilleniaceae		*Hibbertia*	*acerosa*	Needle Leaved Guinea Flower
		Hibbertia	*cuneiformis*	Cutleaf Hibbertia
		Hibbertia	sp.	
Epacridaceae		*Astroloma*	*serratifolium*	Kondrung
		Astroloma	spp.	
		Leucopogon	spp.	
Goodeniaceae		*Dampiera*	spp.	
		Goodenia	sp.	
		Scaevola	sp.	
Haemodoraceae		*Anigozanthos*	*manglesii*	Mangles Kangaro Paw
		Anigozanthos	sp.	
Iridaceae		*Patersonia*	spp.	
Lamiaceae		*Westringia*	spp.	
Lobeliaceae		*Isotoma*	spp.	
Loranthaceae		*Nuytsia*	*floribunda*	Christmas Tree
Malvaceae		*Hibiscus*	sp.	
Mimosaceae		*Acacia*	*acuminata*	Jam
		Acacia	*celastrifolia*	Glowing wattle
		Acacia	chrysella	
		Acacia	decurrens	
		Acacia	*drummondii*	Drummond's Wattle
		Acacia	*lasiocarpa*	Panjang
		Acacia	*pentadenia*	Karri Wattle
		Acacia	*prismifolia*	
		Acacia	*pulchella*	Prickly Moses
	*	*Acacia*	*pycnantha*	Golden Wattle
		Acacia	*saligna*	Coojong
		Acacia	*tetanophylla*	
		Acacia	spp	
Myrtaceae		*Agonis*	*flexuosa*	Peppermint
		Agonis	*linearifolia*	Swamp Peppermint
		Agonis	*parviceps*	
		Baeckea	*muricata*	
		Beaufortia	*schaueri*	
		Beaufortia	*squarrosa*	Sand Bottlebrush

Appendix 2. (continued).

Family		Genus	Species	Common Name
Myrtaceae cont.		*Callistemon*	*phoeniceus*	Lesser Bottlebrush
		Callistemon	spp.	
		Calothamnus	*blepharospermus*	
		Calothamnus	*quadrifidus*	One-sided Bottlebrush
		Calothamnus	*rupestris*	Mouse Ears
		Calothamnus	spp.	
		Calytrix	*brevifolia*	
		Eucalyptus	*accedens*	Powder-bark Wandoo
		Eucalyptus	*aspera*	Rough-leaf range Gum
		Eucalyptus	*burdettiana*	Burdett Gum
		Eucalyptus	*caesia*	Gungurru
		Eucalyptus	*calophylla*	Marri
		Eucalyptus	*camaldulensis*	River Gum
	*	*Eucalyptus*	*capillosa*	
	*	*Eucalyptus*	*citriodora*	
		Eucalyptus	*cladocalyx*	Sugar Gum
		Eucalyptus	*conferruminata*	Bald Island Marlock
		Eucalyptus	*diptera*	Two-winged Gimlet
		Eucalyptus	*diversicolor*	Karri
		Eucalyptus	*eremophila*	Tall Sand Mallee
		Eucalyptus	*erythronema*	Red-flowered Mallee
		Eucalyptus	*ficifolia*	Red-flowering Gum
	*	*Eucalyptus*	*gardneri*	Blue Mallet
	*	*Eucalyptus*	*globulus*	
		Eucalyptus	*grandis*	
		Eucalyptus	*kruseana*	Bookleaf Mallee
	*	*Eucalyptus*	*lehmannii*	Bushy Yate
		Eucalyptus	*leucoxylon*	
		Eucalyptus	*longicornis*	Red Morrel
		Eucalyptus	*loxophleba*	York Gum
		Eucalyptus	*macrandra*	Long-flowered Marlock
		Eucalyptus	*macrocarpa*	Mottlecah
		Eucalyptus	*marginata*	Jarrah
		Eucalyptus	*megacarpa*	Bullich
		Eucalyptus	*mellidora*	
		Eucalyptus	*micranthera*	Alexander River Mallee
		Eucalyptus	*microcorys*	
		Eucalyptus	*occidentalis*	Flat-topped Yate
		Eucalyptus	*patens*	Swan River Blackbutt
		Eucalyptus	*platycorys*	Boorabbin Mallee
	*	*Eucalyptus*	*platypus*	Moort
		Eucalyptus	*robusta*	
		Eucalyptus	*rudis*	Flooded Gum
		Eucalyptus	*salubris*	Gimlet
		Eucalyptus	*sargentii*	Salt River Gum
		Eucalyptus	*sideroxylon*	

Appendix 2. (continued).

Family	Genus	Species	Common Name
Myrtaceae cont.	*Eucalyptus*	*spathulata*	Swamp Mallet
	Eucalyptus	*tetraptera*	Four-winged Mallee
	Eucalyptus	*torquata*	Coral Gum
	Eucalyptus	*wandoo*	Wandoo
	Eucalyptus	spp.	
	Hypocalymma	*angustifolium*	White Myrtle
	Kunzea	*affinis*	
	Kunzea	*baxteri*	Baxter's Kunzea
	Kunzea	*pulchella*	Granite Kunzea
	Leptospermum	*fastigiatum*	
	Leptospermum	spp.	
	Melaleuca	*acuminata*	
	Melaleuca	*corrugata*	
	Melaleuca	*cuticularis*	Saltwater Paperbark
	Melaleuca	*lateritia*	Robin Redbreast Bush
	Melaleuca	*nesophila*	Mindiyed
	Melaleuca	*pungens*	
	Melaleuca	*uncinata*	Broom Brush
	Melaleuca	spp.	
Papilionaceae	*Thryptomene*	*kochii*	
	Verticordia	spp.	
	* *Cytisus*	*proliferus*	Tree Lucerne
	Gastrolobium	*parvifolium*	Berry Poison
	Gastrolobium	*trilobum*	Bullock Poison
	Gastrolobium	sp.	
Pittosporaceae	*Jacksonia*	spp.	
	Kennedia	*prostrata*	Scarlet Runner
	Billardiera	*bicolor*	Painted Marianthus
	Billardiera	sp.	
Proteaceae	*Sollya*	*heterophylla*	Australian Bluebell
	Sollya	sp.	
	Adenanthos	sp.	
	Banksia	*ashbyi*	Ashby's Banksia
	Banksia	*attenuata*	Candlestick Banksia
	Banksia	*burdettii*	Burdett's Banksia
	Banksia	*grandis*	Bull Banksia
	Banksia	*ilicifolia*	Holly-leaved Banksia
	Banksia	*littoralis*	Swamp Banksia
	Banksia	*menziesii*	Firewood Banksia
	Banksia	*prionotes*	Acorn Banksia
	Banksia	*sceptrum*	Sceptre Banksia
	Banksia	*sphaerocarpa*	Round-fruit Banksia
	Dryandra	*carduacea*	Pingle
	Dryandra	*nobilis*	Golden Dryandra
	Dryandra	*sessilis*	Parrot Bush
	Dryandra	spp.	

Appendix 2. (continued).

Family		Genus	Species	Common Name
Proteaceae cont.		*Grevillea*	*acacioides*	
		Grevillea	*curviloba*	
		Grevillea	*drummondii*	Drummond's Grevillea
		Grevillea	*hookeriana*	Red Tooth Brushes
		Grevillea	*paradoxa*	Bottlebrush Grevillea
		Grevillea	*thelemanniana*	Spider Net Grevillea
		Grevillea	*wilsonii*	Native Fuschia
		Grevillea	spp.	
		Hakea	*laurina*	Pincushion Hakea
		Hakea	*lissocarpha*	Honey Bush
		Hakea	*multilineata*	Grass Leaf Hakea
		Hakea	*petiolaris*	Sea Urchin Hakea
		Hakea	*preissii*	Needle Tree
		Hakea	*trifurcata*	Two-leaf Hakea
		Hakea	sp.	
		Xylomelum	*angustifolium*	Sandplain Woody Pear
Rosaceae	*	*Prunis*	*cerasifera*	
Rutaceae		*Chorilaena*	*quercifolia*	Chorilaena
		Diplolaena	*dampieri*	Southern Diplolaena
		Diplolaena	sp.	
		Philotheca	*hassellii*	
Stylidiaceae		*Stylidium*	sp.	
Thymelaeaceae		*Pimelea*	sp.	
Violaceae		*Hybanthus*	*floribundus*	
Xanthorrhoeaceae		*Xanthorrhoea*	*preissii*	Grass Tree

Appendix 3. Number of birds seen during surveys in remnant, revegetated, cleared and regenerated sites from summer 1997 to autumn 1999.

Birds seen	Remnant	Revegetation	Cleared	Regeneration	Total
Australian Wood Duck	1	0	0	0	1
Brown Goshawk	0	1	0	0	1
Laughing Turtle-Dove	0	1	0	0	1
Common Bronzewing	0	4	0	0	4
Crested Pigeon	0	1	0	0	1
Short-billed Black Cockatoo	0	0	0	1	1
Galah	2	7	0	3	12
Rainbow Lorikeet	2	0	0	0	2
Purple-crowned Lorikeet	4	2	0	0	6
Regent Parrot	0	3	0	0	3
Western Rosella	7	17	0	0	24
Australian Ringneck	31	59	1	7	98
Red-capped Parrot	2	11	0	0	13
Elegant Parrot	2	0	0	0	2
Pallid Cuckoo	0	1	0	0	1
Horsfield's Bronze-Cuckoo	0	1	0	0	1
Shining Bronze-Cuckoo	0	0	0	1	1
Laughing Kookaburra	3	3	0	0	6
Sacred Kingfisher	0	0	0	1	1
Rainbow Bee-eater	0	2	0	0	2
Rufous Treecreeper	1	0	0	0	1
Splendid Fairy-wren	0	14	0	1	15
Variegated Fairy-wren	2	0	0	2	4
Spotted Pardalote	0	1	0	0	1
Striated Pardalote	9	3	0	2	14
White-browed Scrubwren	0	9	0	2	11
Weebill	7	4	0	2	13
Western Gerygone	2	10	0	8	20
Inland Thornbill	2	9	0	0	11
Western Thornbill	0	7	0	3	10
Yellow-rumped Thornbill	9	14	0	7	30
Red Wattlebird	26	45	0	1	72
Little Wattlebird	1	12	0	0	13
Wattlebird sp.	0	3	0	0	3
Spiny-cheeked Honeyeater	3	0	0	0	3
Yellow-throated Miner	8	15	0	1	24
Singing Honeyeater	22	48	0	4	74
White-eared Honeyeater	0	1	0	0	1
Purple-gaped Honeyeater	0	1	0	0	1
Sub-total	146	309	1	46	502

Appendix 3. (continued).

Birds seen	Remnant	Revegetation	Cleared	Regeneration	Total
Yellow-plumed Honeyeater	1	1	0	0	2
White-plumed Honeyeater	0	2	0	0	2
Brown-headed Honeyeater	3	3	0	1	7
White-naped Honeyeater	4	7	0	0	11
Brown Honeyeater	35	78	0	6	119
New Holland Honeyeater	25	53	0	0	78
White-cheeked Honeyeater	5	3	0	3	11
White-fronted Honeyeater	1	0	0	0	1
Western Spinebill	8	8	0	0	16
Jacky Winter	0	2	0	0	2
Scarlet Robin	0	3	0	1	4
Red-capped Robin	2	0	0	2	4
Western Yellow Robin	0	1	0	1	2
White-breasted Robin	0	3	0	0	3
White-browed Babbler	2	6	0	0	8
Varied Sittella	1	1	0	0	2
Golden Whistler	1	1	0	0	2
Rufous Whistler	1	5	0	5	11
Grey Shrike-thrush	5	4	0	3	12
Restless Flycatcher	0	1	0	0	1
Magpie-lark	4	6	0	2	12
Grey Fantail	7	30	0	7	44
Willie Wagtail	7	18	1	6	32
Black-faced Cuckoo-shrike	2	0	0	3	5
White-winged Triller	0	0	0	1	1
Black-faced Woodswallow	2	1	0	0	3
Dusky Woodswallow	0	1	0	0	1
Grey Butcherbird	2	1	0	0	3
Pied Butcherbird	1	1	0	0	2
Australian Magpie	7	14	0	2	23
Australian Raven	9	10	0	1	20
Richard's Pipit	0	0	0	1	1
Mistletoebird	1	0	0	2	3
Welcome Swallow	0	3	0	0	3
Tree Martin	1	3	0	0	4
Grey-breasted White-eye	12	34	0	1	47
Sub-total	149	304	1	48	502
Grand Total	295	613	2	94	1004

Appendix 4. Bird species seen during instantaneous bird counts near Toodyay (see text). C = seen in canopy, U = seen in understorey.

	Brown Honeyeater				Singing Honeyeater				White-cheeked Honeyeater			
	Diverse		Wattle		Diverse		Wattle		Diverse		Wattle	
	C	U	C	U	C	U	C	U	C	U	C	U
Week : Day												
1 : 1	26	10	21	0	0	0	0	0	0	0	4	0
1 : 2	48	12	26	0	11	3	13	3	8	2	3	0
1 : 3	44	14	11	2	8	2	4	0	0	0	3	1
Total	118	36	58	2	19	5	17	3	8	2	10	1
2 : 1	51	7	24	0	0	0	3	0	0	0	1	0
2 : 2	39	12	23	4	4	3	4	5	1	1	1	0
2 : 3	17	6	9	16	2	4	2	5	0	2	0	0
Total	107	25	56	20	6	7	9	10	1	3	2	0
3 : 1	44	21	15	0	2	0	0	0	0	1	0	0
3 : 2	24	9	20	3	1	0	1	0	1	0	0	0
3 : 3	53	20	20	3	1	0	2	0	3	1	0	0
Total	121	50	55	6	4	0	3	0	4	2	0	0
4 : 1	27	40	4	0	3	5	0	0	3	0	0	0
4 : 2	97	64	35	3	4	0	0	0	9	4	0	0
Total	124	104	39	3	7	5	0	0	12	4	0	0

	Red Wattlebird				New Holland Honeyeater				Grey-breasted White-eye			
	Diverse		Wattle		Diverse		Wattle		Diverse		Wattle	
	C	U	C	U	C	U	C	U	C	U	C	U
Week : Day												
1 : 1	0	0	0	0	0	0	0	0	33	15	10	0
1 : 2	1	0	1	0	0	0	0	0	36	19	5	2
1 : 3	0	0	0	0	0	0	0	0	20	6	9	1
Total	1	0	1	0	0	0	0	0	89	40	24	3
2 : 1	0	0	0	0	0	0	0	0	28	3	0	0
2 : 2	0	0	0	0	0	0	0	0	22	9	10	2
2 : 3	0	0	0	0	0	0	0	0	29	7	2	0
Total	0	0	0	0	0	0	0	0	79	19	12	2
3 : 1	0	0	0	0	0	0	0	0	9	5	3	0
3 : 2	0	0	0	0	0	0	0	0	5	0	3	0
3 : 3	0	0	0	0	0	0	0	0	1	1	4	0
Total	0	0	0	0	0	0	0	0	15	6	10	0
4 : 1	0	0	0	0	0	0	0	0	2	1	19	0
4 : 2	0	0	0	0	1	1	0	0	5	0	18	1
Total	0	0	0	0	1	1	0	0	7	1	37	1

Appendix 4. (continued) C = seen in canopy, U = seen in understorey.

	Western Gerygone				Weebill				Western Thornbill			
	Diverse		Wattle		Diverse		Wattle		Diverse		Wattle	
	C	U	C	U	C	U	C	U	C	U	C	U
Week : Day												
1 : 1	0	0	0	0	1	1	1	0	0	0	0	0
1 : 2	0	0	0	0	17	4	1	0	0	0	0	0
1 : 3	0	0	0	0	13	3	0	0	3	1	3	0
Total	0	0	0	0	31	8	2	0	3	1	3	0
2 : 1	0	0	0	0	0	0	3	0	0	0	1	0
2 : 2	4	0	2	3	7	1	3	0	0	0	0	0
2 : 3	0	0	0	0	11	4	6	1	0	0	3	0
Total	4	0	2	3	18	5	12	1	0	0	4	0
3 : 1	1	1	2	1	4	0	0	0	0	0	0	0
3 : 2	0	0	2	0	2	0	4	0	0	0	0	0
3 : 3	1	0	2	1	3	2	3	0	0	0	0	0
Total	2	1	6	2	9	2	7	0	0	0	0	0
4 : 1	0	0	10	0	1	1	8	0	1	0	1	0
4 : 2	0	0	0	0	0	0	6	0	1	0	0	0
Total	0	0	10	0	1	1	14	0	2	0	1	0

	Grey Fantail				Splendid Fairy-wren				Welcome Swallow			
	Diverse		Wattle		Diverse		Wattle		Diverse		Wattle	
	C	U	C	U	C	U	C	U	C	U	C	U
Week : Day												
1 : 1	0	0	0	0	0	4	0	0	0	0	0	0
1 : 2	1	0	2	0	1	0	3	2	0	0	1	0
1 : 3	2	0	0	0	0	2	1	0	0	0	1	0
Total	3	0	2	0	1	6	4	2	0	0	2	0
2 : 1	0	1	3	0	0	0	0	0	0	0	0	0
2 : 2	0	0	1	0	0	0	0	0	0	0	0	0
2 : 3	4	1	0	0	0	0	0	0	0	0	0	0
Total	4	2	4	0	0	0	0	0	0	0	0	0
3 : 1	0	0	0	0	0	0	0	0	0	0	0	0
3 : 2	0	0	0	0	0	0	0	0	0	0	0	0
3 : 3	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0	0	0
4 : 1	0	0	0	0	0	0	0	0	0	0	0	0
4 : 2	0	0	2	0	0	0	0	0	0	0	0	0
Total	0	0	2	0	0	0	0	0	0	0	0	0

Appendix 4. (continued) C = seen in canopy, U = seen in understorey.

	Yellow-rumped Thornbill				Inland Thornbill				Striated Pardolote			
	Diverse		Wattle		Diverse		Wattle		Diverse		Wattle	
Week : Day	C	U	C	U	C	U	C	U	C	U	C	U
1 : 1	0	0	0	0	0	0	0	0	0	0	0	0
1 : 2	3	1	0	1	0	0	0	0	0	0	0	0
1 : 3	2	0	2	0	0	0	0	0	0	0	0	0
Total	5	1	2	1	0	0	0	0	0	0	0	0
2 : 1	0	0	3	0	0	0	1	0	0	0	0	0
2 : 2	0	4	3	0	2	0	0	0	0	0	0	0
2 : 3	1	1	0	1	0	0	0	0	0	0	0	0
Total	1	5	6	1	2	0	1	0	0	0	0	0
3 : 1	0	0	0	0	0	0	0	0	0	0	0	0
3 : 2	0	0	0	2	0	0	0	0	0	0	0	0
3 : 3	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	2	0	0	0	0	0	0	0	0
4 : 1	0	0	0	0	0	0	0	0	1	1	0	0
4 : 2	0	0	1	0	0	0	2	0	2	0	0	0
Total	0	0	1	0	0	0	2	0	3	1	0	0

	Rufous Whistler				Australian Ringneck				Shining Bronze-Cuckoo			
	Diverse		Wattle		Diverse		Wattle		Diverse		Wattle	
Week : Day	C	U	C	U	C	U	C	U	C	U	C	U
1 : 1	1	0	13	0	3	0	1	0	0	0	0	0
1 : 2	5	2	8	1	4	0	1	0	0	0	0	0
1 : 3	6	1	12	0	5	0	2	0	0	0	0	0
Total	12	3	33	1	12	0	4	0	0	0	0	0
2 : 1	2	0	19	0	0	0	3	0	0	0	0	0
2 : 2	0	0	16	0	2	0	5	0	0	0	0	0
2 : 3	4	1	1	1	4	0	2	0	0	0	0	0
Total	6	1	36	1	6	0	10	0	0	0	0	0
3 : 1	1	1	2	1	3	0	4	0	0	0	1	0
3 : 2	0	0	1	0	2	0	9	1	0	0	0	0
3 : 3	1	0	5	1	6	0	7	0	0	0	0	2
Total	2	1	8	2	11	0	20	1	0	0	1	2
4 : 1	4	0	0	1	8	0	0	0	0	0	0	0
4 : 2	7	1	6	3	6	0	0	0	0	0	0	0
Total	11	1	6	4	14	0	0	0	0	0	0	0

Appendix 4. (continued) C = seen in canopy, U = seen in understorey.

	Red-capped Parrot				Black-faced Cuckoo-Shrike				Australian Magpie			
	Diverse		Wattle		Diverse		Wattle		Diverse		Wattle	
	C	U	C	U	C	U	C	U	C	U	C	U
Week : Day												
1 : 1	0	0	0	0	5	0	3	0	1	0	0	0
1 : 2	0	0	0	0	1	0	4	0	0	0	0	0
1 : 3	1	0	2	0	1	0	1	0	0	0	0	0
Total	1	0	2	0	7	0	8	0	1	0	0	0
2 : 1	0	0	2	0	0	0	0	0	0	0	0	0
2 : 2	1	0	0	0	0	0	0	0	2	0	1	0
2 : 3	0	0	1	0	1	0	0	0	5	0	0	0
Total	1	0	3	0	1	0	0	0	7	0	1	0
3 : 1	0	0	0	0	0	0	0	0	0	0	1	0
3 : 2	3	0	1	0	0	0	0	0	0	0	0	0
3 : 3	2	0	3	0	0	0	0	0	0	0	0	0
Total	5	0	4	0	0	0	0	0	0	0	1	0
4 : 1	0	0	0	0	0	0	0	0	1	0	0	0
4 : 2	0	0	2	0	1	0	0	1	2	0	0	0
Total	0	0	2	0	1	0	0	1	3	0	0	0

	Unidentified			
	Diverse		Wattle	
	C	U	C	U
Week : Day				
1 : 1	10	3	5	0
1 : 2	0	0	1	0
1 : 3	0	0	0	0
Total	10	3	6	0
2 : 1	14	0	11	2
2 : 2	1	0	3	0
2 : 3	0	0	0	0
Total	15	0	14	2
3 : 1	0	0	0	0
3 : 2	1	1	0	0
3 : 3	0	0	0	0
Total	1	1	0	0
4 : 1	0	3	0	0
4 : 2	0	0	0	0
Total	0	3	0	0